



AGRICULTURAL ACADEMY

INSTITUTE OF AGRICULTURE – KARNOBAT

VESELINA PAVLOVA DOBREVA

**INFLUENCE OF GENOTYPE AND GROWING CONDITIONS
ON THE YIELD AND SEED QUALITY OF NEW
BARLEY VARIETIES**

ABSTRACT

OF THE DISSERTATION
FOR ACQUISITION OF EDUCATIONAL AND SCIENTIFIC
DEGREE "DOCTOR"

**in the scientific specialty
"Breeding and seed production of cultivated plants"**

Scientific supervisor:

Assoc. Prof. Dr. Milka Dimitrova-Doneva

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Scientific Jury:

1. Prof. Dr. Dragomir Valchev
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Karnobat – 2026

The research was conducted in the period 2018-2021 at the Institute of Agriculture - Karnobat. The dissertation is written on 248 pages, contains 55 tables and 62 figures. The list of cited literature includes 334 sources, of which 160 are in Cyrillic and 174 in Latin.

I would like to thank my scientific supervisor, Assoc. Prof. Dr. Milka Dimitrova-Doneva, for her help in developing and shaping this dissertation.

Sincere thanks for the support and assistance of Prof. Dr. Darina Valcheva, as well as to my colleagues from the Institute of Agriculture - Karnobat for their cooperation and useful discussions and advice.

The defense of the dissertation will take place onat..... at the Institute of Agriculture – Karnobat at a meeting of the scientific jury.

The materials for the defense are published on the Internet on the pages of the SSA and the Institute of Agriculture – Karnobat and are available to those interested in the library of the institute.

I. INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the oldest crops cultivated by man, originating from Near East (Iran, Iraq), with wild barley being widespread from North Africa to Tibet. The earliest evidence of cultivation dates back to the Neolithic (Abu Hurayra, Syria).

The grain has high feed value, is rich in protein and essential amino acids, especially lysine. Emmer barley is a valuable raw material for the brewing industry, and naked barley is used for human food.

The crop is distinguished by good adaptability, higher drought resistance and earlier ripening compared to wheat, which ensures stable yields under various conditions.

Worldwide, barley is grown on about 800 million decares, with a significant portion in Russia and China. In Bulgaria, the areas reached a maximum in 1975 (5.7 million decares), then decreased, and after 2020 were below 2 million decares. The average yield increased from 367 kg/da (2000–2018) to 468 kg/da (2018–2021), mainly due to the introduction of new varieties. About 80% of the areas in our country are sown with Bulgarian selection. Over the last 20 years, over 30 new varieties have been created, mainly at the Institute of Agriculture - Karnobat. High-quality seed material is key to the yield potential and stable agricultural production, which determines the importance of variety maintenance and seed production.

II. GOAL AND OBJECTIVES

The goal of this study is to determine the influence of genotype and growing conditions on the yield and quality of seeds in new barley varieties.

To achieve the goal, the following tasks were worked on:

Task 1. Assessment of the genetic potential of new barley varieties for the production of high-yielding and high-quality seeds depending on growing conditions

1.1. Influence of meteorological conditions, nitrogen fertilization and seed rate on the phenological development of the tested varieties.

1.1.1 Duration of phenophases in the tested barley varieties by year, genotypes, seed rates and fertilization rates

1.2. Influence of growing conditions on yield and certain productivity-related traits in new barley varieties

1.2.1. Influence of growing conditions on grain yield and seed yield in barley varieties

1.2.2. Influence of growing conditions on certain productivity-related traits in barley varieties

1.2.3. Relationship between yield and certain productivity-related traits by year

1.2.4. Relationship between yield and certain productivity-related traits by seeding rate

1.2.5. Relationship between yield and certain productivity-related traits by fertilization rate

1.3. Influence of growing conditions on the seed quality of new barley varieties

Task 2. Identification of genotypic differences in the growth activity of seeds of new barley varieties produced under different growing conditions.

III. MATERIAL AND METHODS

During the study period, one field experiment and one field-laboratory study were conducted.

1. Field multifactorial experiment

A field multifactorial experiment was set up in the experimental field of the Institute of Agriculture - Karnobat to establish the influence of genotype and growing conditions on the yield and sowing qualities of seeds of new barley varieties. The study period is three years from the fall of 2018 to the summer of 2021. The object of study are two two-row barley varieties - Kuber and Saira and two six-row barley varieties - Zemela and Bozhin.

The experiment was sown using the block method in 48 variants in four replications of 10 m². The varieties were tested at seeding rates - SR1 - 250, SR2 - 350, SR3 - 450 germinating seeds per m² and nitrogen fertilization with rates F0 - without nitrogen, F1 - N8, F2 - N12, F3 - N16. Nitrogen fertilizer was in the form of ammonium nitrate. In the fall, fertilization was carried out with 20 kg/da triple superphosphate and 12 kg/da potassium chloride. Fertilization was manual, with the entire amount of phosphorus, potassium and 1/3 of the nitrogen fertilizer being applied before sowing, and the remaining 2/3 of the nitrogen - at the beginning of the spring vegetation. Agrotechnical measures that are not the subject of the study are consistent with the adopted cultivation technology for the crop (soil cultivation and plant protection measures). The following indicators were recorded: number of sprouted plants per m²; number of overwintered plants per m²; number of harvested plants per m²; total sibship; number of productive sibs per plant; plant height, (cm); spike length, (cm); number of sterile spikelets per spike; number of grains per spike; grain weight per spike, (g); mass of 1000 grains, (g); harvest index, (g); grain yield, (kg/day); seed yield, (kg/day);

Scheme of the experience

Kuber			Sayra			Zemela			Bozhin		
250g.s.	350g.s.	450g.s.	250g.s.	350g.s	450g.s..	250g.s.	350g.s	450g.s.	250g.s..	350g.s	450g.s.
N16	N0	N8	N0	N8	N12	N8	N12	N16	N12	N16	N0
N12	N16	N0	N16	N0	N8	N0	N8	N12	N8	N12	N16
N8	N12	N16	N12	N16	N0	N16	N0	N8	N0	N8	N12
N0	N8	N12	N8	N12	N16	N12	N16	N0	N16	N0	N8

250g.s.	350g.s.	450g.s.	250g.s.	350g.s	450g.s..	250g.s.	350g.s	450g.s.	250g.s..	350g.s	450g.s.
N0	N8	N12	N8	N12	N16	N12	N16	N0	N8	N12	N16
N16	N0	N8	N0	N8	N12	N8	N12	N16	N12	N16	N0
N12	N16	N0	N16	N0	N8	N0	N8	N12	N16	N0	N8
N8	N12	N16	N12	N16	N0	N16	N0	N8	N0	N8	N12

250g.s.	350g.s.	450g.s.	250g.s.	350g.s	450g.s..	250g.s.	350g.s	450g.s.	250g.s..	350g.s	450g.s.
N8	N12	N16	N12	N16	N0	N16	N0	N8	N0	N8	N12
N0	N8	N12	N8	N12	N16	N12	N16	N0	N16	N0	N8
N16	N0	N8	N0	N8	N12	N8	N12	N16	N12	N16	N0
N12	N16	N0	N16	N0	N8	N0	N8	N12	N8	N12	N16

250g.s.	350g.s.	450g.s.	250g.s.	350g.s	450g.s..	250g.s.	350g.s	450g.s.	250g.s..	350g.s	450g.s.
N12	N16	N0	N16	N0	N8	N0	N8	N12	N16	N0	N8
N8	N12	N16	N12	N16	N0	N16	N0	N8	N0	N8	N12
N0	N8	N12	N8	N12	N16	N12	N16	N0	N8	N12	N16
N16	N0	N8	N0	N8	N12	N8	N12	N16	N12	N16	N0

On permanent 1/4 meter plots, the occurrence and duration in days of the BBCH phenophases were recorded, as for the phenophase to begin, 10% of the plants must have entered it, and mass occurrence is at 75% of the plants.

Field seed germination was calculated by the ratio of the number of germinated plants, expressed as a percentage of the number of germinated seeds, determined in the laboratory germination. The number of overwintered plants is the number of plants surviving at the beginning of spring vegetation, as a percentage of the number of germinated plants. Harvested plants is the number of plants remaining for harvesting as a percentage of the number of

germinated plants. The adaptation coefficient (K_a) is the number of plants remaining for harvesting, as a percentage of the number of germinated seeds, determined by laboratory germination. The coefficient of productive germination of a plant is the productive germination as a percentage of the total germination of a plant. The coefficient of utility is the resulting value of the ratio seed yield : grain yield in %.

After harvest, grain yield (kg/day) was recorded – the plots were harvested mechanically, separately, each variant in four repetitions and seed yield (kg/day). Seed yield is obtained after cleaning the obtained grain, with a seed cleaning machine. Cleaning was carried out separately by variants and repetitions. The fractions that BDS 429-77 defines as seeds for barley are the seeds that remain above the sieves with a diameter of 2.2 and 2.5 mm.

The statistical processing of the results was performed using the software products JMP 5.0.1, SPSS 19, Statgraphics, Statistica 10, using the following analyses: Fit analysis, Analysis of variance, PCA, Correlation analysis, Multiple regression analysis, Path coefficient analysis.

2. Field – laboratory study

Genotypic differences in the growth activity of seeds of winter barley varieties produced under different growing conditions were established. The growing variants are indicated in the field multifactorial experiment. The seeds of each variant were placed in rolls of filter paper of 20 seeds in 4 repetitions. The rolls were placed at room temperature for 10 days, immersed in water. On the 10th day, the following indicators were recorded from the formed 20 plants from each repetition: length of the coleoptile, cm; length of the first leaf, cm; number of roots; length of roots, cm; fresh weight of roots, g; dry weight of roots, g; fresh weight of the first leaf and coleoptile, g; dry weight of the first leaf and coleoptile, g; % dry matter of the first leaf and coleoptile; % dry matter of roots.

The results of the experiment were statistically processed by determining the standard deviation and the coefficient of variation (VC%). The influence of the factors was established by analysis of variance and determining the strength of the factor (η). The SPSS 19 software product was used.

IV. SOIL AND CLIMATE CHARACTERISTICS

The experimental field of the Institute of Agriculture - Karnobat is located in Southeastern Bulgaria. Its soil is chernozem smolnitsa with a heavy mechanical composition. In terms of climate, the region belongs to the transitional-continental climate zone. The study period (2018-2021) in terms of meteorological conditions differs significantly from the temperatures and precipitation typical for the region. The first year of the experiments showed clearly pronounced positive temperature anomalies, combined with a rainfall deficit and a strong unevenness of the rainfall distribution. In the second growing year, the germination of the tested varieties was possible only after the rains in the second half of November. The 2020/2021 growing season can be defined as favorable for the development of barley in meteorological terms. During the three years, the multi-year climate norms for average monthly temperatures were exceeded. The precipitation regime for the period under review is characterized by extremely strong interannual contrast. The data clearly show an unstable and difficult to predict precipitation regime, in which periods of severe drought alternate with periods of significant precipitation.

V. RESULTS AND DISCUSSION

Task 1. Assessment of the genetic potential of new barley varieties for the production of high-yielding and high-quality seeds depending on growing conditions

1.1 Influence of meteorological conditions, nitrogen fertilization and seeding rate on the phenological development of the tested varieties.

1.1.1 Duration of phenophases in the tested barley varieties by year, genotypes, seeding rates and fertilization rates

The experiments conducted made it possible to track the influence of environmental conditions and genotype on the duration of phenophases in the barley varieties tested (Figures 1–23). The first phase encompasses germination and emergence. During the first year, conditions were unfavorable due to a prolonged drought lasting from the summer through the autumn of 2018, which significantly delayed emergence; the duration of this phase reached 92–98 days. In the second year, the phase lasted 22–31 days, again constrained by a lack of precipitation during the autumn of 2019. In the third year, the duration of the phase is close to normal – 10–12 days for two-row varieties and 12–13 days for multi-row varieties. In the first year, the 1-3 leaf phase occurs unusually, in winter, due to late germination and lasts 11–15 days, with no proven varietal differences. In the second year, the phase occurs in November and lasts 19–25 days. In the third year, the phase is the shortest – 7 days for two-row varieties, and longer for multi-row varieties. Tillering is a key phase for yield formation. In the first year, the phase occurs late due to delayed germination and lasts 61–67 days. In the second year, tillering occurs within normal terms and lasts 115–126 days. In the third year, the phase lasts 149 days for two-row varieties, and 141 days for multi-row varieties. The stem elongation and spindle phase is the most sensitive phase for barley to drought and high temperatures. In the first two years, the varieties are placed in conditions of severe drought and high temperatures. Conditions in the third year are more favorable (close to normal temperatures and more precipitation), with the phase lasting 23–27 days. Class emergence, earing and flowering are critical phases in terms of moisture. The first year the phase lasts 7-8 days. In the second year it lasts 8-14 days. In the third year the phase is 10-15 days. In the first two years there are no differences in agrotechnical factors, while in the third year differences in seeding rates and fertilization are found. The milky maturity phase is associated with the accumulation of dry matter and is of great importance for the formation of the yield. In the three years it takes place in conditions of drought and higher temperatures, which reflects on its duration. The waxy and full maturity phase is the final phase. High temperatures and lack of moisture in 2019 and 2020 accelerated ripening, while rainfall in mid-June 2021 made the process smoother.

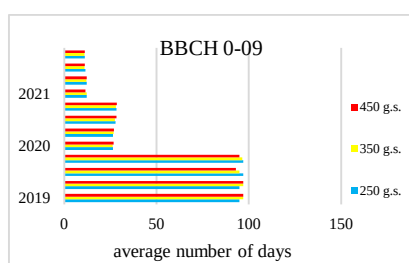


Figure 1

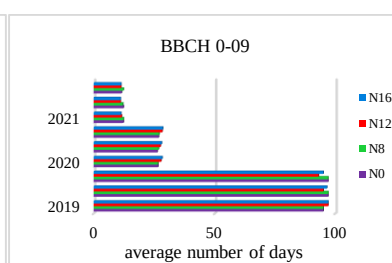


Figure 2

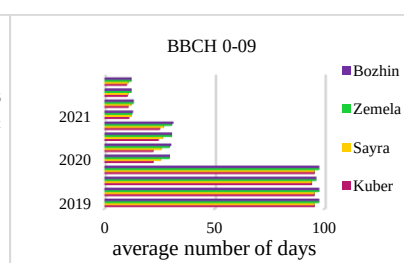


Figure 3

Figures 1, 2, 3. Duration of germination and emergence phase (BBCH 0-09) in average number of days for barley varieties under different growing conditions by year for the period 2018-2021

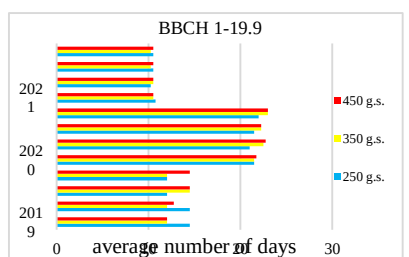


Figure 4

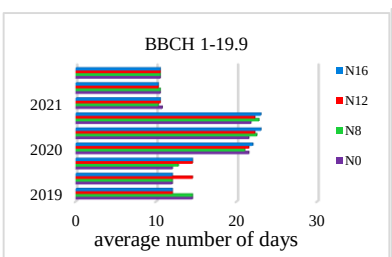


Figure 5

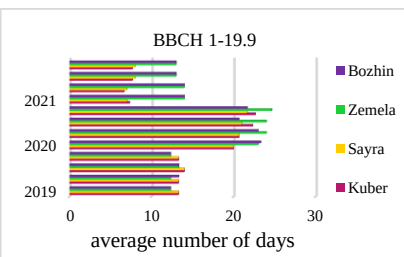


Figure 6

Figures 4, 5, 6. Duration of leaf development phase (BBCH 1-19.9) in average number of days for barley varieties under different growing conditions by year for the period 2018-2021

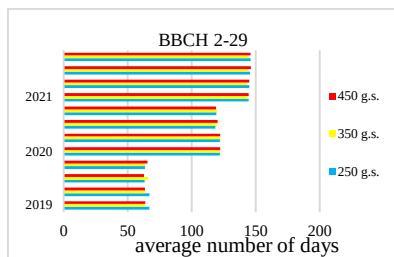


Figure 7

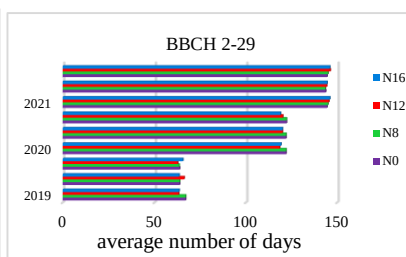


Figure 8

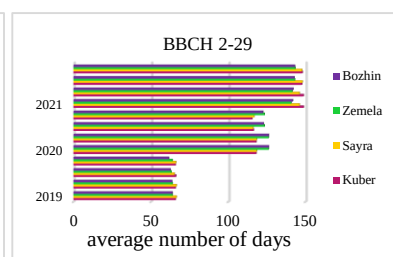


Figure 9

Figures 7, 8, 9. Duration of the tillering phase (BBCH 2-29) in average number of days for barley varieties under different growing conditions by year for the period 2018-2021

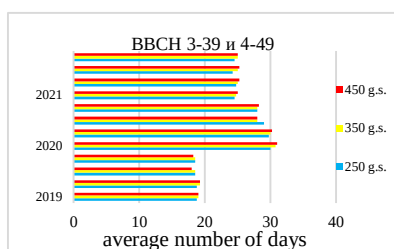


Figure 10

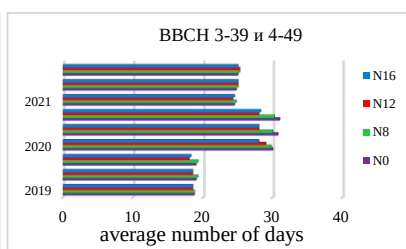


Figure 11

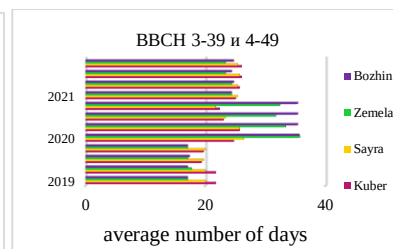


Figure 12

Figures 10, 11, 12. Duration of the stem elongation and spindle phase (BBCH 3-39 and 4-49) in average number of days in barley varieties under different growing conditions by year for the period 2018-2021

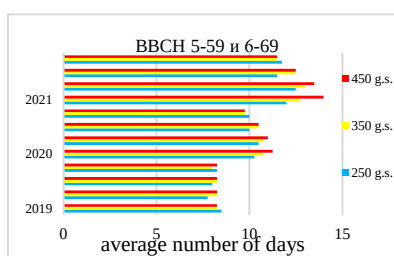


Figure 13

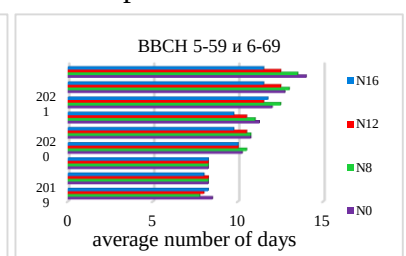


Figure 14

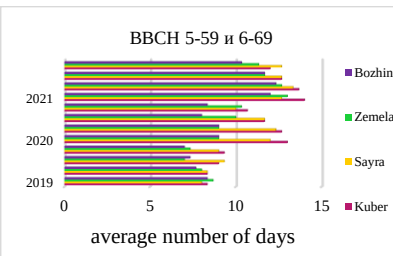


Figure 15

Figures 13, 14, 15. Duration of the ear emergence, earing, flowering phase (BBCH 5-59 and 6-69) in average number of days for barley varieties under different growing conditions by year for the period 2018-2021

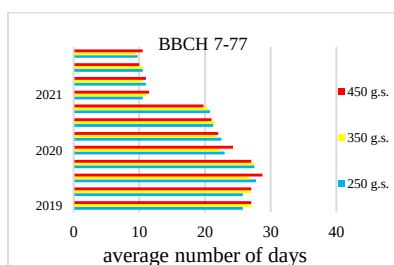


Figure 16

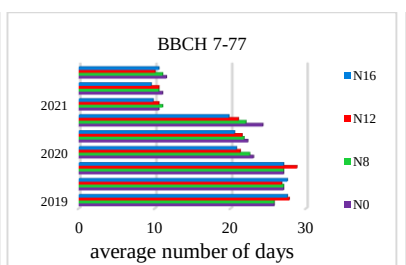


Figure 17

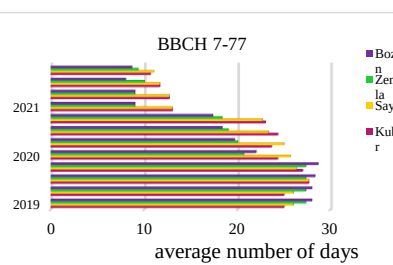


Figure 18

Figures 16, 17, 18. Duration of the milk maturity phase (BBCH 7-77) in average days for barley varieties under different growing conditions by year for the period 2018-2021

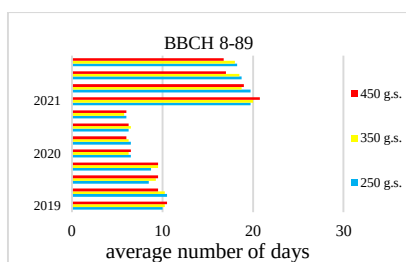


Figure 19

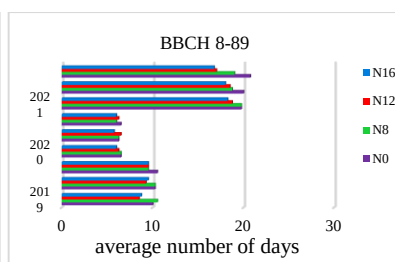


Figure 20

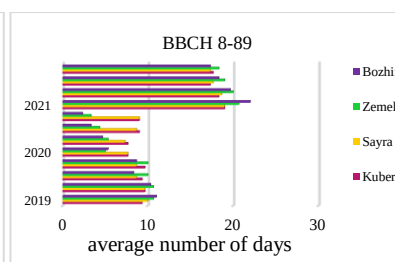


Figure 21

Figures 19, 20, 21. Duration of waxy and full maturity phase (BBCH 8-89) in average number of days for barley varieties under different growing conditions by year for the period 2018-2021

1.1.2. Field germination, overwintering, surviving plants and plant adaptation coefficients

The results obtained show a clear influence of meteorological conditions on germination, field germination and plant survival (Figures 22-33). The most unfavorable year was 2019, when late germination and the smallest number of plants were observed due to prolonged drought, as well as the lowest field germination. In contrast, 2021 was characterized by the best conditions - the highest germination and the largest number of plants, due to the presence of sufficient soil moisture at sowing. The seed rate has an expected effect, with higher rates leading to a greater number of germinated and harvested plants. High nitrogen rates, especially during drought, show a tendency to suppress germination, which is most clearly expressed in 2019. Winter conditions during the period are not a limiting factor, as no significant frost losses were recorded, and the percentage of overwintered plants remains high.

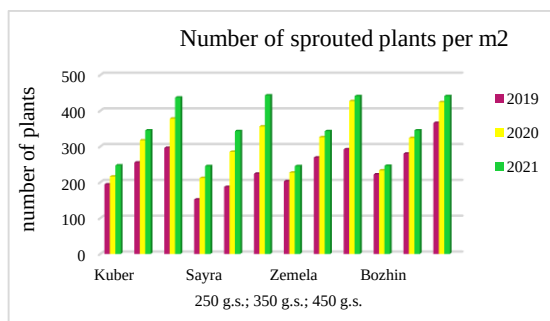


Figure 22

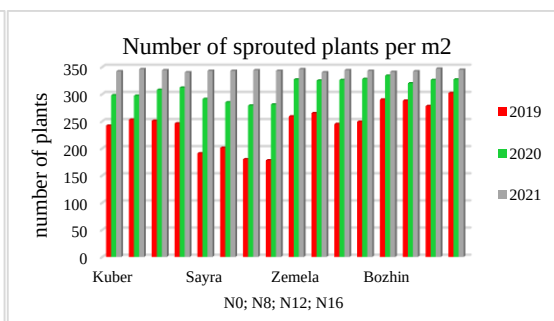


Figure 23

Figures 22 and 23. Number of sprouted plants per m2 of barley varieties under different growing conditions by year for the period 2018-2021

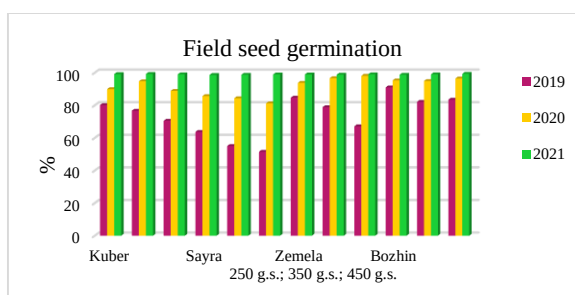


Figure 24

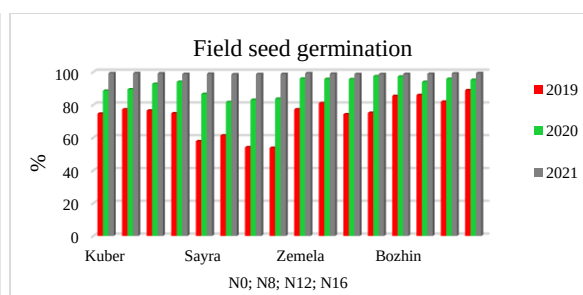


Figure 25

Figures 24 and 25. Field germination of barley varieties under different growing conditions by year for the period 2018-2021

The adaptation coefficient (Ka) confirms the general trend - lowest in 2019 and highest in 2021, clearly reflecting the influence of climatic conditions. In summary, the leading factor for the formation of crop density and final productivity are moisture conditions during the germination period, while the role of nitrogen fertilization remains secondary and highly dependent on specific climatic conditions.

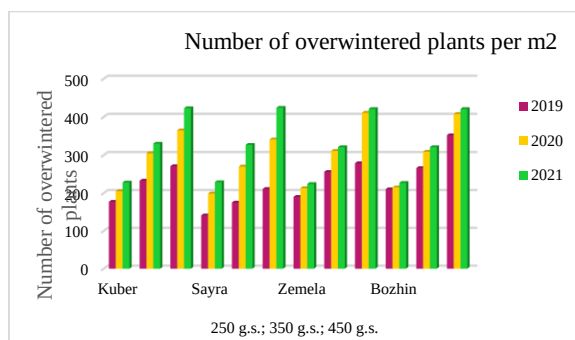


Figure 26

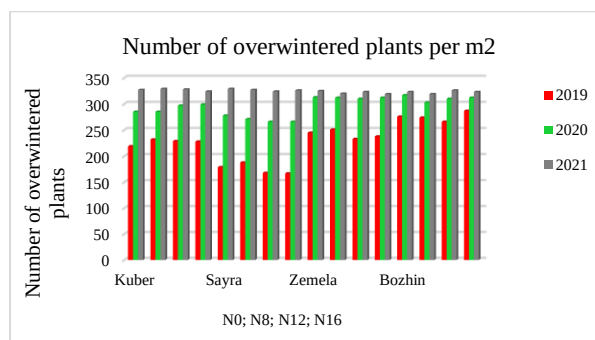


Figure 27

Figures 26 and 27. Number of overwintered plants per m2 of barley varieties under different growing conditions by year for the period 2018-2021

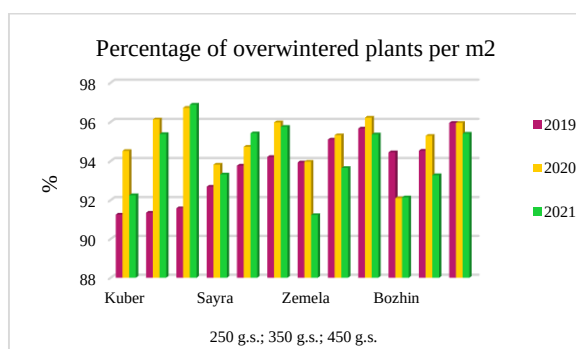


Figure 28

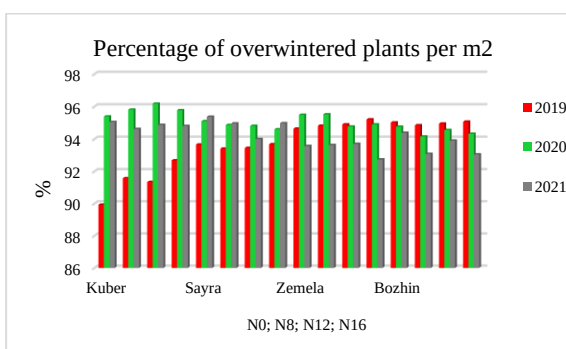


Figure 29

Figures 28 and 29. Percentage of overwintered plants per m2 of barley varieties under different growing conditions by year for the period 2018-2021

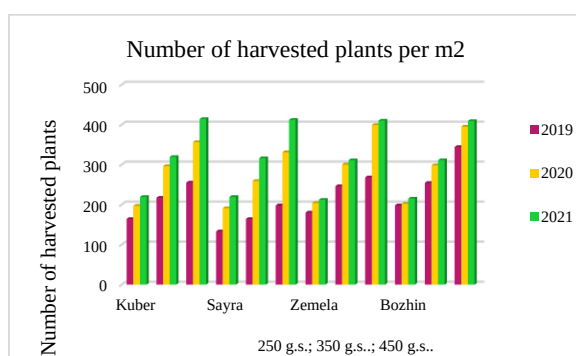


Figure 30

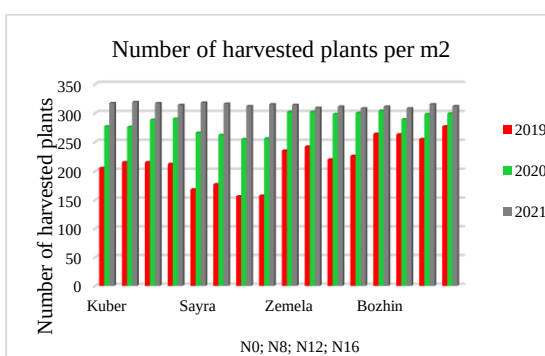


Figure 31

Figures 30 and 31. Number of harvested plants per m2 of barley varieties under different growing conditions by year for the period 2018-2021

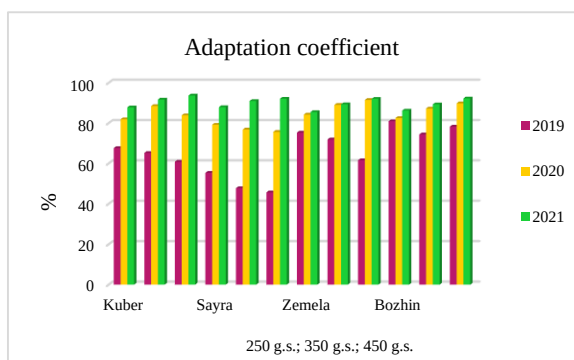


Figure 32

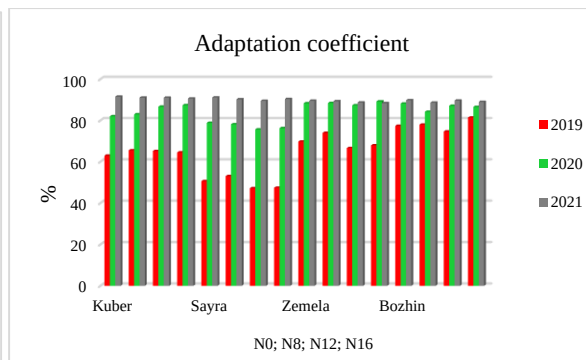


Figure 33

Figures 32 and 33. The adaptation coefficient of barley varieties under different growing conditions by year for the period 2018-2021

1.2. Influence of growing conditions on yield and some indicators related to productivity in new barley varieties

1.2.1. Influence of growing conditions on grain yield and seed yield in barley varieties

Tables 1 and 2 analyze the grain and seed yield of the studied varieties. The results obtained show that the grain and seed yield of barley is most dependent on the conditions of the year, with 2020 standing out as the most unfavorable (376 kg/da), due to severe drought.

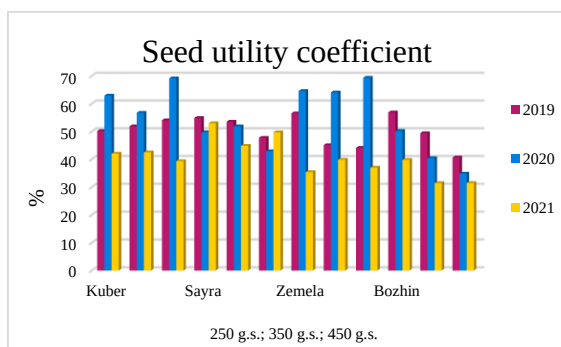


Figure 34

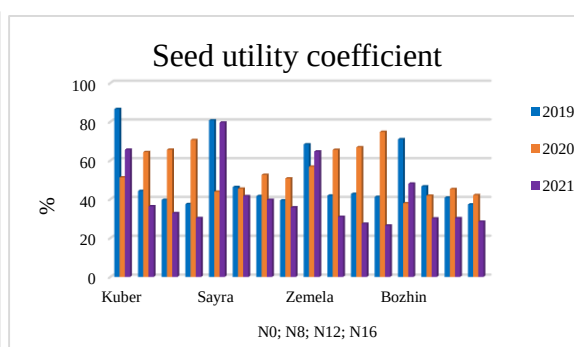


Figure 35

Figures 34 and 35. Seed efficiency coefficient (%) for winter barley varieties grown at different fertilization levels and seeding rates by year for the period 2019-2021

Significantly higher yields were achieved in 2019 and 2021 (538 and 545 kg/da), which confirms the leading role of climatic factors. For all varieties, the lowest values are recorded in 2020, which emphasizes their sensitivity to water deficit. Seed yield follows a similar trend, being lowest in 2020. The utility coefficient varies significantly by year, being lowest in 2021 (40.49%) due to drought during the grain filling phase, and highest in 2020, when, despite the low yield, larger grains with a higher relative share of seeds are formed (Figures 34 and 35).

Table 1. Grain yield of winter barley varieties grown at different fertilization levels and seeding rates by year and average for the period 2019-2021

Factors	Grain yield from da																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	260 ^b	285 ^{ab}	301 ^a	282 ^b	39.08	282 ^a	303 ^a	354 ^a	313 ^{ab}	84.03	306 ^b	401 ^a	410 ^a	372 ^a	75.37	307 ^b	352 ^b	406 ^a	355 ^{ab}	331	57.11	82.07
N8	595 ^a	550 ^a	548 ^a	564 ^a	47.55	510 ^a	529 ^a	610 ^a	550 ^a	137.84	530 ^b	609 ^b	655 ^a	598 ^a	101.27	434 ^c	547 ^b	670 ^a	550 ^a	566	86.15	138.14
N12	696 ^a	654 ^{ab}	564 ^b	638 ^a	111.17	585 ^a	589 ^a	642 ^a	605 ^a	129.00	504 ^b	573 ^{ab}	619 ^a	565 ^a	90.56	537 ^b	550 ^b	770 ^a	619 ^a	607	86.90	152.23
N16	760 ^a	694 ^{ab}	580 ^b	678 ^a	115.33	653 ^a	633 ^a	638 ^a	641 ^a	149.20	507 ^b	655 ^a	669 ^a	611 ^a	65.22	578 ^b	651 ^b	753 ^a	661 ^a	648	84.61	146.62
Mean	578	546	498	540 ^a		508	514	561	528 ^a		462	560	589	537 ^a		464	525	650	546 ^a	538		118.73
LSD for fertilization	87.59	75.80	84.43			133.61	108.52	125.31			56.44	97.82	84.00			87.16	57.46	82.62				
	2020 year																					
N0	414 ^a	381 ^a	450 ^a	415 ^{ab}	212.75	436 ^a	528 ^a	482 ^a	482 ^a	22.33	444 ^a	330 ^a	309 ^a	361 ^b	241.39	376 ^a	530 ^a	472 ^a	459 ^{ab}	429	262.77	114.41
N8	305 ^a	430 ^a	254 ^a	330 ^{ab}	199.96	475 ^{ab}	367 ^b	566 ^a	469 ^a	177.52	261 ^a	378 ^a	255 ^a	298 ^b	225.05	382 ^a	382 ^a	525 ^a	430 ^{ab}	382	233.48	162.39
N12	402 ^a	337 ^a	276 ^a	338 ^{ab}	292.28	370 ^a	424 ^a	408 ^a	401 ^a	202.54	294 ^a	247 ^a	285 ^a	275 ^b	142.13	276 ^a	479 ^a	407 ^a	387 ^{ab}	350	223.58	118.09
N16	269 ^a	416 ^a	232 ^a	305 ^{ab}	289.89	462 ^a	359 ^a	478 ^a	433 ^a	256.80	232 ^a	291 ^a	187 ^a	237 ^b	181.18	332 ^a	355 ^a	487 ^a	391 ^a	342	201.07	144.26
Mean	348	391	303	347 ^{bc}		436	420	484	447 ^a		308	312	259	293 ^c		342	437	473	417 ^{ab}	376		87.11
LSD for fertilization	253.75	273.35	196.59			238.27	204.99	179.85			209.50	213.44	153.52			151.18	242.48	260.12				
	2021 year																					
N0	305 ^a	300 ^a	315 ^a	243 ^c	71.85	204 ^a	263 ^a	260 ^a	242 ^c	75.08	340 ^a	277 ^a	324 ^a	314 ^b	95.51	365 ^a	433 ^a	453 ^a	417 ^a	304	111.42	69.37
N8	522 ^a	528 ^a	614 ^a	555 ^{ab}	116.52	422 ^a	510 ^a	522 ^a	485 ^b	110.47	653 ^a	665 ^a	604 ^a	641 ^a	130.40	552 ^b	677 ^{ab}	771 ^a	667 ^a	587	169.97	129.11
N12	601 ^a	582 ^a	658 ^a	614 ^{ab}	148.05	470 ^a	577 ^a	479 ^a	509 ^b	117.52	729 ^a	642 ^a	720 ^a	697 ^a	137.81	487 ^b	738 ^a	717 ^a	647 ^{ab}	617	157.22	154.28
N16	664 ^a	629 ^a	687 ^a	660 ^{ab}	130.99	562 ^{ab}	640 ^a	475 ^b	559 ^b	110.58	789 ^a	678 ^b	684 ^b	717 ^a	73.95	627 ^a	700 ^a	629 ^a	652 ^{ab}	647	176.30	108.71
Mean	523	510	569	534 ^{ab}		415	498	434	449 ^b		628	566	583	592 ^a		508	637	643	596 ^a	545		93.16
LSD for fertilization	135.60	81.01	123.98			119.51	82.08	97.99			136.23	101.35	80.49			140.74	114.30	186.80				
	Average for the period																					
N0	326	322	355	334		307	365	366	346		363	336	348	349		349	438	444	410	355		
N8	474	502	472	483		469	469	566	501		481	551	505	512		456	535	655	549	511		
N12	566	524	499	530		475	530	510	505		509	504	542	518		433	589	631	551	525		
N16	564	580	500	548		558	544	530	544		509	541	513	521		512	569	623	568	545		
Mean	483	482	457	474		452	477	493	474		466	483	477	475		438	533	588	520	484		

Table 2. Seed yield of winter barley varieties grown at different fertilization levels and seeding rates by year and average for the period 2019-2021

Factors	Seed yield from da																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	249 ^a	249 ^a	249 ^a	249 ^a	1.42	248 ^a	248 ^a	248 ^a	248 ^b	1.63	248 ^a	247 ^a	247 ^a	247 ^c	0.99	247 ^a	247 ^a	247 ^a	247 ^c	248	1.65	0.55
N8	249 ^a	249 ^a	249 ^a	249 ^a	1.74	248 ^a	248 ^a	248 ^a	248 ^a	1.29	247 ^a	247 ^a	246 ^a	247 ^b	2.67	246 ^a	246 ^a	247 ^a	246 ^b	248	2.33	0.95
N12	249 ^a	249 ^a	249 ^a	249 ^a	1.22	248 ^a	248 ^a	248 ^a	248 ^a	1.83	246 ^a	244 ^a	247 ^a	246 ^b	3.93	246 ^a	245 ^{ab}	244 ^b	245 ^b	247	1.81	1.73
N16	249 ^a	249 ^a	248 ^a	248 ^a	1.27	249 ^a	248 ^a	249 ^a	249 ^a	1.54	247 ^a	247 ^a	247 ^a	247 ^b	2.67	243 ^a	243 ^a	242 ^a	243 ^c	247	2.40	0.95
Mean	249	249	249	249 ^a		248	248	248	248 ^b		247	246	247	247 ^c		246	245	245	245 ^d	247		0.76
LSD for fertilization	1.55	1.29	1.29			1.83	1.48	1.22			1.33	3.71	2.44			1.92	1.55	2.42				
	2020 year																					
N0	195 ^a	195 ^a	196 ^a	195 ^a	2.64	196 ^a	196 ^a	196 ^a	196 ^a	2.55	191 ^a	189 ^a	190 ^a	190 ^a	11.25	156 ^a	165 ^a	144 ^a	155 ^b	184	46.40	10.00
N8	193 ^a	195 ^a	194 ^a	194 ^a	4.86	196 ^{ab}	194 ^b	197 ^a	196 ^a	1.81	186 ^a	187 ^a	188 ^a	187 ^a	13.83	168 ^a	149 ^a	163 ^a	160 ^b	184	39.69	9.49
N12	193 ^a	194 ^a	195 ^a	194 ^a	3.93	194 ^a	196 ^a	195 ^a	195 ^a	2.80	185 ^a	181 ^a	183 ^a	183 ^b	13.49	167 ^a	154 ^a	152 ^a	158 ^c	183	28.86	8.02
N16	194 ^a	193 ^a	194 ^a	194 ^a	2.37	195 ^a	194 ^a	195 ^a	195 ^a	3.25	182 ^a	187 ^a	182 ^a	184 ^b	18.44	159 ^a	157 ^a	143 ^a	153 ^c	182	54.31	8.69
Mean	194	194	195	195 ^a		195	195	196	196 ^a		186	186	186	186 ^b		163	156	151	157 ^c	184		5.73
LSD for fertilization	4.27	3.16	2.77			2.83	2.66	2.11			13.23	13.80	14.87			43.38	44.17	37.52				
	2021 year																					
N0	198 ^b	198 ^b	198 ^a	198 ^a	0.36	195 ^a	197 ^a	197 ^a	196 ^b	3.03	196 ^a	197 ^a	196 ^a	196 ^b	1.85	196 ^a	196 ^a	196 ^a	196 ^b	197	5.40	1.22
N8	197 ^a	198 ^a	198 ^a	198 ^a	0.95	196 ^b	196 ^b	197 ^a	196 ^b	0.70	194 ^a	195 ^a	196 ^a	195 ^c	2.44	192 ^a	193 ^a	193 ^a	193 ^d	196	2.78	1.34
N12	197 ^a	198 ^a	198 ^a	198 ^a	1.67	196 ^a	195 ^a	195 ^a	195 ^a	1.31	190 ^a	184 ^a	191 ^a	188 ^b	7.82	183 ^a	183 ^a	190 ^a	185 ^b	192	10.49	5.29
N16	197 ^a	197 ^a	197 ^a	197 ^a	2.03	196 ^a	194 ^a	194 ^a	195 ^{ab}	2.69	192 ^a	189 ^{ab}	183 ^b	188 ^b	6.78	187 ^a	180 ^a	175 ^a	181 ^c	190	16.05	7.23
Mean	197	198	198	198 ^a		196	196	196	196 ^b		193	191	192	192 ^c		190	188	189	189 ^d	194		1.43
LSD for fertilization	1.57	1.55	0.83			2.88	1.57	1.48			3.25	6.45	5.38			5.01	12.34	10.22				
	Average for the period																					
N0	214	214	214	214		213	214	214	214		212	211	211	211		200	203	196	200	210		
N8	213	214	213	213		213	213	214	213		209	210	210	210		202	196	201	200	209		
N12	213	214	214	214		213	213	213	213		207	203	207	206		199	194	195	196	207		
N16	213	213	213	213		213	212	213	213		207	208	204	206		196	193	187	192	206		
Mean	213	214	214	214		213	213	214	213		209	208	208	208		199	197	195	197	208		

Table 3 presents an analysis of variance, which confirms that year is the leading factor (up to 88.82% in seed yield), followed by genotype and the interaction year $\times$ genotype. The role of genotype and seed rate is significantly weaker. For achieving high yield and good quality of production, climatic conditions and properly balanced nitrogen fertilization are of the greatest importance, and in drought conditions, lower fertilizer rates (N0–N8) should be preferred.

Table 3. Analysis of the variance of grain yield, seed yield and utility coefficient of winter barley varieties grown at different fertilization levels and seeding rates for the period 2019-2021

Factors	Grain yield		Seed yield		Utility coefficient	
	MS	η	MS	η	MS	η
Year	172.825***	25.84	227907.848* **	88.82	20349.354***	25.37
Genotype	7.356***	1.65	8894.813***	5.20	9463.829***	7.87
Seeding rates	10.079***	1.51	74.883*	0.03	2352.474***	2.94
Fertilization	104.418***	23.42	406.239**	0.24	39644.0080***	32.93
Year $\times$ Genotype	18.971***	8.51	3938.441***	4.60	16259.538***	6.76
Year $\times$ Seeding rates	1.321***	0.39	34.066 n.s.	0.03	608.002***	0.37
Year $\times$ Fertilization	55.178***	24.75	78.957*	0.09	46578.942***	19.34
Genotype $\times$ Seeding rates	7.001***	3.14	67.568*	0.08	3338.287***	1.38
Genotype $\times$ Fertilization	0.754***	0.51	104.369**	0.18	2022.925***	0.57
Seeding rates $\times$ Fertilization	1.174***	0.53	62.180 n.s.	0.07	825.562***	0.34
Year $\times$ Genotype $\times$ Seeding rates	3.388***	3.04	44.291 n.s.	0.10	3670.065***	0.77
Year $\times$ Genotype $\times$ Fertilization	1.347***	1.81	37.049 n.s.	0.13	4322.309***	0.59
Year $\times$ Seeding rates $\times$ Fertilization	0.479***	0.43	37.055 n.s.	0.09	718.114***	0.14
Genotype $\times$ Seeding rates $\times$ Fertilization	1.215***	1.63	37.601 n.s.	0.13	2032.215***	0.28
Year $\times$ Genotype $\times$ Seeding rates $\times$ Fertilization	1.056***	2.84	29.108 n.s.	0.21	4973.777***	0.35

1.2.2. Influence of growing conditions on some indicators related to productivity in barley varieties

Tables 4 to 12 present the results for some indicators related to productivity in barley varieties grown under different conditions. Data on total tillering varies by year, with the highest average value recorded in 2021 and the lowest in 2020. Productive tillering is also highest in 2021 and lowest in 2020, indicating a strong influence of climatic conditions. Plant height varies significantly between years and varieties. The highest values were recorded in 2019 and the lowest in 2020 due to severe drought. Genotypic differences are clearly expressed, with some varieties responding more strongly to environmental conditions. The length of the spike is strongly influenced by the climatic conditions of the year, with the highest values recorded in 2019 and the lowest in 2020. The number of grains in the spike depends mainly on the genetic characteristics of the varieties, but is also strongly influenced by climatic conditions. The highest values were obtained in 2019 and 2021, and the lowest in 2020. The number of sterile spikelets in the spike is strongly influenced by climatic conditions, with the highest values observed in 2020 and the lowest in 2019. The weight of the grain per spike varies significantly depending on the conditions of the year, with the highest values recorded in 2019 and the lowest in 2020. Genotypic differences are clearly expressed. The mass of 1000 grains is mainly influenced by the conditions of the year, with the highest values in 2019 and the lowest in 2020.

Table 4. General plant vigor of barley varieties under different growing conditions by year and average for the period 2019-2021

Factors	General plant fraternity by variant																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	2.4 ^a	3.40 ^a	3.38 ^a	3.07 ^b	0.90	4.84 ^a	4.44 ^{ab}	3.58 ^b	4.29 ^a	1.15	3.07 ^a	3.23 ^a	3.33 ^a	3.21 ^b	0.86	3.35 ^a	2.97 ^{ab}	2.44 ^b	2.92 ^b	3.37	0.75	0.92
N8	5.3 ^a	4.59 ^a	4.43 ^a	4.78 ^b	1.40	6.07 ^a	6.28 ^a	5.86 ^a	6.07 ^a	1.92	4.12 ^a	3.84 ^a	3.32 ^a	3.76 ^c	0.83	4.12 ^a	3.49 ^a	3.33 ^a	3.65 ^c	4.57	0.97	0.74
N12	5.4 ^a	5.38 ^a	6.21 ^a	5.68 ^a	1.67	7.34 ^a	6.07 ^a	5.72 ^a	6.38 ^a	3.62	4.35 ^a	3.90 ^a	3.53 ^a	3.93 ^b	1.51	3.51 ^a	3.51 ^a	3.77 ^a	3.60 ^b	4.90	1.38	0.99
N16	5.2 ^a	4.97 ^a	4.20 ^a	4.82 ^b	2.90	6.46 ^a	6.21 ^a	6.23 ^a	6.30 ^a	1.36	3.83 ^a	3.95 ^a	2.95 ^a	3.58 ^c	1.13	3.62 ^a	4.32 ^a	3.30 ^a	3.75 ^c	4.61	1.08	0.90
Mean	4.6	4.59	4.56	4.59 ^b		6.18	5.75	5.35	5.76		3.84	3.73	3.28	3.62 ^c		3.65	3.57	3.21	3.48 ^c	4.36		0.53
LSD for fertilization	1.96	1.33	2.05			2.18	2.62	1.50			0.74	1.37	1.02			0.94	0.85	1.26				
	2020 year																					
N0	4.77 ^a	4.07 ^a	4.58 ^a	4.47 ^{ab}	1.02	5.02 ^a	4.52 ^a	4.77 ^a	4.77 ^a	1.24	4.40 ^{ab}	4.64 ^a	3.52 ^b	4.19 ^{ab}	1.02	3.91 ^{ab}	4.23 ^a	3.03 ^b	3.72 ^b	4.29	1.15	0.90
N8	4.73 ^a	4.92 ^a	4.83 ^a	4.83 ^{ab}	0.99	5.72 ^a	5.00 ^{ab}	4.73 ^b	5.15 ^a	0.95	3.87 ^a	4.45 ^a	3.97 ^a	4.10 ^{bc}	0.90	3.97 ^a	4.14 ^a	3.18 ^a	3.76 ^c	4.46	1.13	0.74
N12	4.76 ^a	5.36 ^a	4.45 ^a	4.86 ^a	2.15	5.17 ^a	5.23 ^a	4.68 ^a	5.03 ^a	1.22	3.78 ^a	3.27 ^a	3.43 ^a	3.49 ^b	1.02	3.47 ^a	3.95 ^a	3.72 ^a	3.71 ^b	4.27	0.84	0.62
N16	3.57 ^a	4.25 ^a	4.80 ^a	4.21 ^{ab}	1.36	4.73 ^a	4.85 ^a	4.57 ^a	4.72 ^a	1.61	4.09 ^a	3.76 ^a	3.60 ^a	3.82 ^b	0.93	4.03 ^a	4.09 ^a	3.58 ^a	3.90 ^b	4.16	1.45	0.69
Mean	4.46	4.65	4.67	4.59 ^a		5.16	4.90	4.69	4.92 ^a		4.04	4.03	3.63	3.90 ^b		3.85	4.10	3.38	3.77 ^b	4.30		0.49
LSD for fertilization	1.22	1.57	1.37			1.46	1.20	0.98			1.09	0.59	1.05			0.81	1.48	0.98				
	2021 year																					
N0	4.32 ^a	4.07 ^a	4.57 ^a	4.32 ^{ab}	1.85	5.00 ^{ab}	3.97 ^b	5.08 ^a	4.68 ^a	1.06	3.97 ^a	3.90 ^a	3.38 ^b	3.75 ^{bc}	0.41	3.60 ^a	3.15 ^a	3.65 ^a	3.47 ^c	4.06	0.72	0.74
N8	5.10 ^a	5.53 ^a	5.42 ^a	5.35 ^a	0.99	6.20 ^a	5.25 ^a	5.47 ^a	5.64 ^a	1.27	4.08 ^a	4.53 ^a	4.08 ^a	4.23 ^b	0.72	4.08 ^a	4.53 ^a	3.92 ^a	4.18 ^b	4.85	0.86	0.65
N12	5.33 ^a	5.62 ^a	5.63 ^a	5.53 ^a	1.60	5.42 ^a	6.10 ^a	5.63 ^a	5.72 ^a	0.88	4.03 ^a	4.17 ^a	4.00 ^a	4.07 ^b	0.68	4.85 ^a	3.90 ^a	4.35 ^a	4.37 ^b	4.92	1.24	0.58
N16	5.38 ^a	5.28 ^a	5.58 ^a	5.42 ^a	1.20	5.87 ^a	5.4 ^a	6.22 ^a	5.84 ^a	1.42	4.27 ^a	4.47 ^a	4.45 ^a	4.40 ^b	0.66	4.40 ^a	4.08 ^a	4.75 ^a	4.41 ^b	5.02	1.18	0.51
Mean	5.03	5.13	5.30	5.15 ^a		5.62	5.19	5.60	5.47 ^a		4.09	4.27	3.98	4.11 ^b		4.23	3.92	4.17	4.11 ^b	4.71		0.32
LSD for fertilization	1.44	1.22	1.53			1.29	0.83	1.22			0.59	0.68	0.55			1.22	0.74	0.92				
	Average for the period																					
N0	3.84	3.85	4.18	3.96		4.95	4.31	4.48	4.58		3.81	3.92	3.41	3.71		3.62	3.45	3.04	3.37	3.91		
N8	5.05	5.01	4.89	4.98		6.00	5.51	5.35	5.62		4.02	4.27	3.79	4.03		4.06	4.05	3.48	3.86	4.62		
N12	5.18	5.45	5.43	5.35		5.98	5.80	5.34	5.71		4.05	3.78	3.65	3.83		3.94	3.79	3.95	3.89	4.70		
N16	4.75	4.83	4.86	4.81		5.69	5.50	5.67	5.62		4.06	4.06	3.67	3.93		4.02	4.16	3.88	4.02	4.60		
Mean	4.71	4.79	4.84	4.78		5.66	5.28	5.21	5.38		3.99	4.01	3.63	3.88		3.91	3.86	3.59	3.79	4.46		

Table 5. Productive yield per plant of barley varieties under different growing conditions by year and average for the period 2019-2021

Factors	Number of productive siblings per plant by variant																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	1.90 ^a	2.41 ^a	2.34 ^a	2.22 ^b	0.57	3.15 ^a	3.20 ^a	2.50 ^b	2.95 ^a	0.59	1.94 ^a	1.82 ^a	2.00 ^a	1.92 ^{bc}	0.77	2.05 ^a	1.46 ^b	1.44 ^b	1.65 ^c	2.19	0.54	0.55
N8	4.03 ^a	3.87 ^a	3.32 ^a	3.74 ^b	1.15	4.63 ^a	4.84 ^a	4.63 ^a	4.70 ^a	1.43	3.00 ^a	2.86 ^{ab}	2.27 ^b	2.71 ^c	0.71	3.17 ^a	2.76 ^a	2.51 ^a	2.81 ^c	3.49	0.75	0.60
N12	4.24 ^{ab}	3.52 ^b	4.64 ^a	4.13 ^a	0.97	5.50 ^a	4.68 ^a	4.33 ^a	4.84 ^a	2.53	3.28 ^a	2.76 ^a	2.68 ^a	2.91 ^b	1.11	2.88 ^a	2.63 ^a	2.92 ^a	2.81 ^b	3.67	0.99	0.85
N16	3.97 ^a	3.44 ^a	3.23 ^a	3.55 ^b	2.01	4.91 ^a	4.45 ^a	4.65 ^a	4.67 ^a	1.13	2.97 ^a	2.87 ^{ab}	2.21 ^b	2.68 ^c	0.75	2.77 ^a	3.55 ^a	2.75 ^a	3.02 ^{bc}	3.48	0.86	0.72
Mean	3.54	3.31	3.38	3.41^b		4.55	4.29	4.03	4.29^a		2.80	2.58	2.29	2.56^c		2.72	2.60	2.41	2.58^c	3.21		0.39
LSD for fertilization	1.24	0.83	1.55			1.24	2.14	0.96			0.61	0.98	0.81			0.74	0.65	0.92				
	2020 year																					
N0	3.63 ^a	3.30 ^a	3.42 ^a	3.45 ^a	1.20	4.15 ^a	3.77 ^a	3.73 ^a	3.88 ^a	1.29	2.52 ^a	2.78 ^a	2.15 ^a	2.48 ^b	0.84	2.61 ^a	2.85 ^a	2.22 ^a	2.56 ^b	3.09	0.68	0.51
N8	3.75 ^a	3.70 ^a	3.55 ^a	3.67 ^a	0.79	4.25 ^a	3.50 ^a	3.47 ^a	3.74 ^a	1.04	2.78 ^a	3.00 ^a	2.71 ^a	2.83 ^b	0.61	2.65 ^a	2.79 ^a	2.22 ^a	2.55 ^b	3.20	0.99	0.53
N12	3.79 ^a	4.11 ^a	3.45 ^a	3.78 ^a	1.38	3.87 ^a	3.92 ^a	3.53 ^a	3.77 ^a	1.15	2.58 ^a	2.47 ^a	2.00 ^a	2.35 ^b	0.77	2.48 ^a	2.65 ^a	2.62 ^a	2.58 ^b	3.12	0.66	0.49
N16	2.92 ^a	2.98 ^a	3.57 ^a	3.16 ^a	1.15	3.55 ^a	3.62 ^a	3.20 ^a	3.46 ^a	1.38	2.78 ^a	2.32 ^a	2.35 ^a	2.48 ^b	0.59	2.53 ^a	2.71 ^a	2.70 ^a	2.65 ^b	2.94	0.63	0.49
Mean	3.52	3.52	3.50	3.52^a		3.96	3.70	3.48	3.71^a		2.66	2.64	2.30	2.54^b		2.57	2.75	2.44	2.59^b	3.09		0.32
LSD for fertilization	1.09	1.11	1.13			1.26	1.05	1.20			0.94	0.33	0.65			0.72	0.85	0.57				
	2021 year																					
N0	3.15 ^a	3.38 ^a	3.77 ^a	3.43 ^{ab}	1.20	4.03 ^{ab}	3.20 ^b	4.33 ^a	3.85 ^a	0.90	2.55 ^a	2.97 ^a	2.67 ^a	2.73 ^{bc}	0.61	2.43 ^b	2.13 ^b	3.10 ^a	2.55 ^c	3.14	0.45	0.81
N8	4.63 ^a	4.72 ^a	4.80 ^a	4.72 ^a	1.13	5.68 ^a	4.63 ^a	5.05 ^a	5.12 ^a	1.11	3.45 ^a	3.50 ^a	3.20 ^a	3.38 ^b	0.72	3.62 ^a	3.92 ^a	3.28 ^a	3.61 ^b	4.21	0.88	0.60
N12	4.63 ^a	4.88 ^a	5.10 ^a	4.87 ^a	1.27	4.83 ^a	5.57 ^a	5.18 ^a	5.19 ^a	0.75	3.20 ^b	3.62 ^a	3.08 ^b	3.30 ^b	0.38	4.20 ^a	3.35 ^a	3.65 ^a	3.73 ^b	4.27	1.04	0.65
N16	4.85 ^a	4.58 ^a	4.90 ^a	4.78 ^a	1.20	5.25 ^a	4.83 ^a	5.68 ^a	5.25 ^a	1.18	3.23 ^b	3.72 ^a	3.52 ^{ab}	3.49 ^b	0.45	3.92 ^a	3.48 ^a	3.82 ^a	3.74 ^b	4.32	0.84	0.53
Mean	4.32	4.39	4.64	4.45^a		4.95	4.56	5.06	4.86^a		3.11	3.45	3.12	3.23^c		3.54	3.22	3.46	3.41^c	3.99		0.37
LSD for fertilization	1.18	1.05	1.22			1.24	0.72	0.85			0.48	0.52	0.59			1.05	0.55	0.74				
	Average for the period																					
N0	2.89	3.03	3.18	3.03		3.78	3.39	3.52	3.56		2.34	2.52	2.27	2.38		2.36	2.15	2.25	2.25	2.81		
N8	4.14	4.10	3.89	4.04		4.85	4.32	4.38	4.52		3.08	3.12	2.73	2.98		3.15	3.16	2.67	2.99	3.63		
N12	4.22	4.17	4.40	4.26		4.73	4.72	4.35	4.60		3.09	2.95	2.59	2.88		3.19	2.88	3.06	3.04	3.70		
N16	3.91	3.67	3.90	3.83		4.57	4.30	4.51	4.46		2.99	2.97	2.69	2.88		3.07	3.25	3.09	3.14	3.58		
Mean	3.79	3.74	3.84	3.79		4.48	4.18	4.19	4.29		2.88	2.89	2.57	2.78		2.94	2.86	2.77	2.86	3.43		

Table 6. Plant height of barley varieties under different growing conditions by year and average for the period 2019-2021

Factors	Plant height																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s.	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s.	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s.	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s.	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	75.91 ^b	83.11 ^a	82.10 ^a	80.37 ^c	3.62	89.32 ^a	89.47 ^a	83.49 ^a	87.43 ^b	7.64	97.44 ^a	95.98 ^a	97.21 ^a	96.88 ^a	4.61	81.26 ^a	79.24 ^a	80.18 ^a	80.23 ^c	86.23	7.43	5.04
N8	98.55 ^a	97.81 ^{ab}	95.13 ^b	97.16 ^b	3.23	99.71 ^a	104.70 ^a	102.20 ^a	102.20 ^b	11.23	112.85 ^a	111.10 ^a	105.36 ^b	109.77 ^a	3.93	95.37 ^b	97.40 ^a	101.22 ^a	98.00 ^b	101.78	4.25	5.47
N12	103.77 ^a	102.96 ^a	101.22 ^a	102.65 ^c	4.23	106.93 ^a	108.59 ^a	106.14 ^a	107.22 ^b	4.97	114.97 ^a	113.85 ^a	109.85 ^b	112.89 ^a	3.88	103.41 ^a	102.19 ^a	102.97 ^a	102.86 ^c	106.40	4.04	3.12
N16	103.19 ^a	104.17 ^a	96.18 ^a	101.18 ^c	8.79	107.92 ^a	107.18 ^a	106.91 ^a	107.34 ^{ab}	6.22	111.57 ^a	110.51 ^a	112.45 ^a	111.51 ^a	5.47	101.76 ^b	106.23 ^a	104.08 ^a	104.02 ^{bc}	106.01	2.24	4.74
Mean	95.36	97.01	93.66	95.34 ^c		100.97	102.49	99.69	101.05 ^b		109.21	107.86	106.22	107.76 ^a		95.45	96.27	97.11	96.28 ^c	100.11		2.61
LSD for fertilization	5.21	4.36	6.06			9.24	5.71	7.41			3.47	5.73	3.49			4.77	4.21	5.06				
	2020 year																					
N0	61.48 ^a	56.22 ^a	64.10 ^a	60.60 ^a	16.88	65.62 ^a	72.60 ^a	67.07 ^a	68.43 ^a	19.45	62.77 ^a	71.47 ^a	57.48 ^a	63.91 ^a	21.74	69.16 ^a	67.25 ^a	57.70 ^a	64.70 ^a	64.41	19.66	10.21
N8	65.62 ^a	66.18 ^a	56.47 ^a	62.76 ^a	12.56	73.22 ^a	63.27 ^a	68.52 ^a	68.34 ^a	17.94	56.62 ^a	65.85 ^a	64.80 ^a	62.42 ^a	18.23	63.02 ^a	65.14 ^a	61.53 ^a	63.23 ^a	64.19	19.32	8.62
N12	62.83 ^a	68.47 ^a	59.15 ^a	63.48 ^{ab}	18.91	68.18 ^a	70.12 ^a	69.13 ^a	69.14 ^a	14.03	59.78 ^a	57.43 ^a	59.98 ^a	59.06 ^b	11.50	56.58 ^a	66.85 ^a	61.83 ^a	61.75 ^b	63.36	17.69	6.77
N16	55.33 ^a	58.85 ^a	62.67 ^a	58.95 ^b	21.38	70.67 ^a	67.97 ^a	68.53 ^a	69.06 ^a	22.33	67.78 ^a	61.48 ^{ab}	57.45 ^b	62.24 ^{ab}	10.10	63.07 ^a	68.40 ^a	69.28 ^a	66.92 ^a	64.29	14.01	6.93
Mean	61.32	62.43	60.60	61.45 ^b		69.42	68.49	68.31	68.74 ^a		61.74	64.06	59.93	61.91 ^b		62.96	66.91	62.59	64.15 ^b	64.06		3.16
LSD for fertilization	16.70	16.00	18.53			19.49	16.61	17.85			17.68	13.39	15.30			17.72	16.55	17.29				
	2021 year																					
N0	72.00 ^a	71.97 ^a	71.12 ^a	71.70 ^b	4.66	86.93 ^a	73.53 ^b	73.42 ^b	77.96 ^{ab}	4.95	86.12 ^a	81.42 ^b	81.02 ^b	82.85 ^a	3.98	79.45 ^a	72.42 ^b	76.52 ^a	76.13 ^{ab}	77.16	6.42	8.50
N8	91.05 ^a	91.23 ^a	92.00 ^a	91.43 ^d	5.28	97.87 ^a	96.28 ^a	94.12 ^a	96.09 ^c	4.18	110.68 ^a	107.43 ^a	106.53 ^a	108.21 ^a	6.01	103.95 ^a	105.15 ^a	104.23 ^a	104.44 ^b	100.04	6.60	2.82
N12	96.17 ^a	96.77 ^a	93.85 ^a	95.60 ^c	3.64	101.13 ^a	96.92 ^b	98.87 ^{ab}	98.97 ^c	4.07	114.28 ^a	113.05 ^a	110.63 ^a	112.65 ^a	5.70	109.17 ^a	104.92 ^a	100.10 ^b	104.73 ^b	102.99	4.47	5.24
N16	97.90 ^{ab}	100.50 ^a	95.48 ^b	97.96 ^c	4.77	100.25 ^a	101.05 ^a	97.68 ^a	99.66 ^c	4.77	112.45 ^a	114.95 ^a	112.73 ^a	113.38 ^a	4.61	107.88 ^a	110.85 ^a	108.57 ^a	109.10 ^b	105.03	3.28	3.49
Mean	89.28	90.12	88.11	89.17 ^d		96.55	91.95	91.02	93.17 ^c		105.88	104.21	102.73	107.19 ^a		100.11	98.33	97.36	98.60 ^b	97.03		3.86
LSD for fertilization																						
	Average for the period																					
N0	69.80	70.43	72.44	70.89		80.62	78.53	74.66	77.94		87.11	86.29	81.90	85.10		76.62	72.97	71.47	73.69	76.91		
N8	85.07	85.07	81.20	83.78		90.27	88.08	88.28	88.88		93.38	94.79	92.23	93.47		87.45	89.23	88.99	88.56	88.67		
N12	87.59	89.40	84.74	87.24		92.08	91.88	91.38	91.78		96.34	94.78	93.49	94.87		89.72	91.32	88.30	89.78	90.92		
N16	85.47	87.84	84.78	86.03		92.95	92.07	91.04	92.02		97.27	95.65	94.21	95.71		90.90	95.16	93.98	93.35	91.78		
Mean	81.98	83.19	80.79	81.99		88.98	87.64	86.34	87.66		93.53	92.88	90.46	92.29		86.17	87.17	85.69	86.35	87.05		

Table 7. Ear length of barley varieties grown in different growing conditions by year and average for the period 2019-2021

Factors	Class length																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	7.67 ^a	8.14 ^a	8.11 ^a	7.97 ^a	1.04	8.94 ^a	8.98 ^a	7.82 ^b	8.58 ^a	0.95	5.41 ^a	5.13 ^{ab}	4.87 ^b	5.14 ^b	0.43	5.09 ^a	4.89 ^{ab}	4.61 ^b	4.86 ^b	6.64	0.43	0.76
N8	9.07 ^a	8.91 ^a	8.86 ^a	8.95 ^b	0.90	9.25 ^a	9.56 ^a	9.18 ^a	9.33 ^a	1.08	5.69 ^a	5.43 ^b	5.26 ^b	5.46 ^c	0.25	5.48 ^a	5.28 ^a	5.29 ^a	5.35 ^c	7.27	0.27	0.32
N12	9.35 ^a	9.17 ^a	9.41 ^a	9.31 ^a	0.81	9.80 ^a	10.00 ^a	9.32 ^a	9.71 ^a	1.24	5.97 ^a	5.69 ^{ab}	5.65 ^b	5.77 ^b	0.32	5.64 ^a	5.53 ^a	5.42 ^a	5.53 ^b	7.58	0.38	0.40
N16	9.43 ^a	9.17 ^a	8.86 ^a	9.15 ^a	0.59	9.79 ^a	9.65 ^a	9.41 ^a	9.62 ^a	0.63	6.00 ^a	5.58 ^b	5.52 ^b	5.70 ^b	0.27	5.78 ^a	5.47 ^b	5.13 ^c	5.46 ^b	7.48	0.16	0.51
Mean	8.88	8.85	8.81	8.85 ^b		9.45	9.55	8.93	9.31 ^a		5.77	5.46	5.33	5.52 ^c		5.50	5.29	5.11	5.30 ^c	7.24		0.42
LSD for fertilization	0.81	0.85	0.83			1.07	0.83	1.00			0.26	0.31	0.37			0.33	0.35	0.26				
	2020 year																					
N0	6.68 ^a	6.52 ^a	6.72 ^a	6.64 ^b	0.75	7.78 ^a	7.71 ^a	7.51 ^a	7.67 ^a	0.77	3.98 ^a	4.25 ^a	3.96 ^a	4.06 ^c	0.47	4.14 ^a	4.24 ^a	4.01 ^a	4.13 ^c	5.63	0.59	0.25
N8	7.06 ^a	7.08 ^a	6.24 ^b	6.79 ^b	0.43	8.09 ^a	7.59 ^a	7.39 ^a	7.69 ^a	1.11	3.96 ^a	4.28 ^a	4.00 ^a	4.08 ^c	0.63	4.24 ^a	4.03 ^a	4.17 ^a	4.15 ^c	5.68	0.47	0.60
N12	7.08 ^a	7.09 ^a	6.84 ^a	7.00 ^b	1.24	7.81 ^a	8.01 ^a	7.57 ^a	7.80 ^a	0.79	3.98 ^a	3.90 ^a	3.80 ^a	3.89 ^c	0.50	4.13 ^a	4.15 ^a	3.98 ^a	4.09 ^c	5.70	0.47	0.28
N16	6.60 ^a	6.19 ^a	6.86 ^a	6.55 ^b	1.22	8.04 ^a	7.73 ^a	7.51 ^a	7.76 ^a	0.90	4.19 ^a	3.93 ^a	3.72 ^a	3.95 ^c	0.50	4.14 ^a	4.28 ^a	4.22 ^a	4.21 ^c	5.62	0.25	0.46
Mean	6.86	6.72	6.67	6.75 ^b		7.93	7.76	7.50	7.73 ^a		4.03	4.09	3.87	4.00 ^c		4.16	4.18	4.10	4.15 ^c	5.66		0.21
LSD for fertilization	1.00	1.05	0.74			0.83	0.74	1.00			0.52	0.26	0.68			0.41	0.46	0.46				
	2021 year																					
N0	6.62 ^a	6.33 ^a	6.24 ^a	6.40 ^a	0.45	7.46 ^a	6.19 ^b	6.47 ^b	6.71 ^a	0.47	5.33 ^a	5.29 ^a	4.38 ^b	5.00 ^b	0.71	5.02 ^a	4.39 ^b	4.25 ^b	4.55 ^b	5.66	0.34	0.92
N8	7.60 ^a	7.59 ^a	7.76 ^a	7.65 ^a	0.52	7.90 ^a	7.64 ^{ab}	7.41 ^b	7.65 ^a	0.38	5.73 ^a	5.64 ^a	5.68 ^a	5.68 ^b	0.32	6.15 ^a	5.77 ^a	5.61 ^a	5.84 ^b	6.71	0.66	0.37
N12	8.09 ^a	7.98 ^a	7.31 ^a	7.79 ^a	0.84	8.11 ^a	7.71 ^b	7.60 ^b	7.81 ^a	0.36	5.93 ^a	5.45 ^a	5.60 ^a	5.66 ^b	0.52	5.76 ^a	5.88 ^a	5.33 ^b	5.66 ^b	6.73	0.43	0.60
N16	8.02 ^a	8.08 ^a	7.55 ^a	7.88 ^a	0.79	7.96 ^a	8.07 ^a	7.67 ^a	7.90 ^a	0.84	5.59 ^a	5.38 ^a	5.64 ^a	5.54 ^b	0.29	5.93 ^a	5.62 ^a	5.67 ^a	5.74 ^b	6.77	0.43	0.39
Mean	7.58	7.50	7.22	7.43 ^a		7.86	7.40	7.29	7.52 ^a		5.65	5.44	5.33	5.47 ^b		5.72	5.42	5.22	5.45 ^b	6.47		0.44
LSD for fertilization	0.46	0.78	0.65			0.44	0.59	0.57			0.37	0.59	0.41			0.68	0.35	0.26				
	Average for the period																					
N0	6.99	7.00	7.02	7.00		8.06	7.63	7.27	7.65		4.91	4.89	4.40	4.73		4.75	4.51	4.29	4.52	5.98		
N8	7.91	7.86	7.62	7.80		8.41	8.26	7.99	8.22		5.13	5.12	4.98	5.08		5.29	5.03	5.02	5.11	6.55		
N12	8.17	8.08	7.85	8.03		8.57	8.57	8.16	8.43		5.29	5.01	5.02	5.11		5.18	5.19	4.91	5.09	6.67		
N16	8.02	7.81	7.76	7.86		8.60	8.48	8.20	8.43		5.26	4.96	4.96	5.03		5.28	5.12	5.01	5.14	6.62		
Mean	7.77	7.69	7.56	7.67		8.41	8.24	7.91	8.19		5.15	5.00	4.84	5.00		5.13	4.96	4.81	4.97	6.46		

Table 8. Number of grains per spike in barley varieties grown under different conditions by year and average for the period 2019-2021

Factors	Number of grains in a class																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin					LSD for seeding rates	LSD average for sowing rates
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year		
Year	2019 year																					
N0	23.21 ^a	25.20 ^a	24.54 ^a	24.32 ^c	2.73	28.33 ^a	28.09 ^a	24.62 ^b	27.01 ^c	3.05	77.48 ^a	70.46 ^{ab}	66.42 ^b	71.45 ^a	9.67	66.16 ^a	63.06 ^{ab}	58.85 ^b	62.69 ^b	46.37	6.28	6.68
N8	27.67 ^a	26.97 ^a	27.26 ^a	27.30 ^c	1.85	27.99 ^a	29.64 ^a	28.35 ^a	28.66 ^c	2.40	83.13 ^a	80.72 ^a	75.66 ^b	79.84 ^a	3.66	72.91 ^a	70.54 ^b	68.89 ^b	70.78 ^b	51.65	2.01	4.16
N12	28.55 ^a	27.62 ^a	28.50 ^a	28.22 ^c	2.06	29.38 ^a	30.00 ^a	28.49 ^a	29.29 ^c	2.71	84.81 ^a	81.34 ^a	80.67 ^a	82.27 ^a	4.47	74.02 ^a	72.36 ^{ab}	69.35 ^b	71.91 ^b	52.92	3.84	3.19
N16	28.78 ^a	28.30 ^a	26.38 ^b	27.82 ^c	1.40	29.53 ^a	29.63 ^a	29.31 ^a	29.49 ^c	1.60	83.77 ^a	80.95 ^a	78.51 ^a	81.08 ^a	5.56	75.19 ^a	70.95 ^b	67.07 ^c	71.07 ^b	52.37	3.27	4.71
Mean	27.05	27.02	26.67	26.92 ^c		28.81	29.34	27.69	28.61 ^c		82.30	78.37	75.32	78.66 ^a		72.07	69.23	66.04	69.11 ^b	50.83		4.44
LSD for fertilization	2.44	1.87	1.57			2.27	1.77	3.03			2.79	5.49	8.50			3.34	4.27	4.34				
	2020 year																					
N0	22.58 ^a	21.48 ^a	21.62 ^a	21.89 ^b	2.60	25.07 ^a	24.73 ^a	24.12 ^a	24.64 ^b	3.16	55.25 ^a	60.13 ^a	50.45 ^a	55.28 ^a	11.87	55.30 ^a	55.20 ^a	51.25 ^a	53.92 ^a	38.93	11.00	5.11
N8	23.40 ^a	23.22 ^a	20.52 ^b	22.38 ^b	1.76	27.20 ^a	24.90 ^a	24.30 ^a	25.47 ^b	3.89	50.15 ^a	59.10 ^a	53.44 ^a	54.23 ^a	11.72	52.55 ^a	49.62 ^a	50.30 ^a	50.82 ^a	38.23	7.75	4.97
N12	23.59 ^a	23.51 ^a	22.03 ^a	23.04 ^c	4.16	26.38 ^a	26.53 ^a	24.57 ^a	25.83 ^b	2.21	53.65 ^a	52.70 ^a	50.70 ^a	52.35 ^a	6.89	50.12 ^a	51.85 ^a	48.35 ^a	50.11 ^a	37.83	7.39	2.54
N16	21.05 ^a	19.27 ^a	21.92 ^a	20.74 ^b	4.59	26.98 ^a	25.47 ^a	24.75 ^a	25.73 ^b	3.12	59.47 ^a	50.84 ^b	46.95 ^b	52.42 ^a	8.02	49.55 ^a	50.53 ^a	50.90 ^a	50.33 ^a	37.31	3.75	6.31
Mean	22.66	21.87	21.52	22.02 ^c		26.41	25.41	24.44	25.42 ^b		54.63	55.69	50.39	53.57 ^a		51.88	51.80	50.20	51.30 ^a	38.08		3.00
LSD for fertilization	3.38	3.66	2.99			2.64	2.64	3.73			9.92	6.91	11.25			8.26	7.74	6.78				
	2021 year																					
N0	21.88 ^a	20.88 ^a	20.70 ^a	21.15 ^b	1.47	25.82 ^a	21.58 ^b	21.73 ^b	23.04 ^b	2.10	70.45 ^a	66.15 ^a	56.80 ^b	64.47 ^a	6.98	64.40 ^a	55.00 ^b	51.05 ^b	56.82 ^a	41.37	6.80	9.52
N8	25.43 ^a	25.12 ^a	25.37 ^a	25.31 ^c	1.58	27.58 ^a	26.03 ^{ab}	25.58 ^b	26.40 ^c	1.63	82.20 ^a	81.55 ^a	80.90 ^a	81.55 ^a	5.99	77.25 ^a	75.10 ^{ab}	71.75 ^b	74.70 ^b	51.99	5.20	2.86
N12	27.25 ^a	27.08 ^a	24.92 ^b	26.42 ^c	1.42	27.42 ^a	26.40 ^b	26.23 ^b	26.68 ^c	0.72	83.30 ^a	79.65 ^a	81.60 ^a	81.52 ^a	4.25	76.65 ^a	72.90 ^{ab}	67.05 ^b	72.20 ^b	51.71	7.86	5.06
N16	27.82 ^a	27.58 ^{ab}	25.55 ^b	26.98 ^c	2.10	27.60 ^a	27.13 ^a	26.08 ^a	26.94 ^c	2.03	84.05 ^a	78.55 ^a	81.80 ^a	81.47 ^a	6.78	77.20 ^a	70.30 ^b	73.70 ^{ab}	73.73 ^b	52.28	5.90	4.39
Mean	25.60	25.17	24.14	24.97 ^c		27.11	25.29	24.91	25.77 ^c		80.00	76.48	75.28	77.25 ^a		73.88	68.33	65.89	69.37 ^b	49.34		4.69
LSD for fertilization	1.70	1.61	1.48			1.50	1.26	2.07			7.19	6.45	3.25			7.63	5.38	5.58				
	Average for the period																					
N0	22.56	22.52	22.29	22.46		26.41	24.80	23.49	24.90		67.73	65.58	57.89	63.73		61.95	57.75	53.72	57.81	42.23		
N8	25.50	25.10	24.38	24.99		27.59	26.86	26.08	26.84		71.83	73.79	70.00	71.87		67.57	65.09	63.65	65.44	47.29		
N12	26.46	26.07	25.15	25.89		27.73	27.64	26.43	27.27		73.92	71.23	70.99	72.05		66.93	65.70	61.58	64.74	47.49		
N16	25.88	25.05	24.62	25.18		28.04	27.41	26.71	27.39		75.76	70.11	69.09	71.65		67.31	63.93	63.89	65.04	47.32		
Mean	25.10	24.69	24.11	24.63		27.44	26.68	25.68	26.60		72.31	70.18	66.99	69.83		65.94	63.12	60.71	63.26	46.08		

Table 9. Number of sterile spikelets per spike in barley varieties grown under different conditions by year and average for the period 2019-2021

Factors	Number of sterile spikelets in the cluster																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	0.99 ^a	0.85 ^a	0.78 ^a	0.87 ^b	0.63	1.69 ^a	1.74 ^a	1.61 ^a	1.68 ^b	0.66	10.29 ^a	7.40 ^{ab}	7.05 ^b	8.25 ^a	2.92	7.91 ^a	9.00 ^a	9.12 ^a	8.68 ^a	4.87	2.33	1.80
N8	0.66 ^a	0.57 ^a	0.79 ^a	0.67 ^c	0.36	0.96 ^a	1.29 ^a	0.88 ^a	1.04 ^c	0.61	8.63 ^a	9.16 ^a	8.20 ^a	8.66 ^a	1.74	7.21 ^a	7.46 ^a	7.60 ^a	7.42 ^b	4.45	0.90	0.53
N12	0.51 ^a	0.48 ^a	0.53 ^a	0.51 ^c	0.32	0.83 ^a	1.41 ^a	0.84 ^a	1.03 ^c	0.66	7.89 ^a	8.51 ^a	8.03 ^a	8.14 ^a	1.04	7.95 ^a	6.97 ^a	7.07 ^a	7.33 ^b	4.25	1.27	0.67
N16	0.51 ^a	0.60 ^a	0.66 ^a	0.59 ^d	0.34	1.09 ^a	1.05 ^a	1.29 ^a	1.14 ^c	0.34	9.08 ^a	8.32 ^a	8.52 ^a	8.64 ^a	2.57	6.58 ^a	6.55 ^a	6.91 ^a	6.68 ^b	4.26	0.95	0.44
Mean	0.67	0.63	0.69	0.66^d		1.14	1.37	1.16	1.22^c		8.97	8.35	7.95	8.42^a		7.41	7.50	7.68	7.53^b	4.46		0.51
LSD for fertilization	0.33	0.44	0.50			0.63	0.63	0.39			1.55	2.11	2.55			1.48	1.61	1.13				
	2020 year																					
N0	3.72 ^a	3.32 ^{ab}	1.67 ^b	2.90 ^c	1.92	2.10 ^{ab}	1.37 ^b	3.03 ^a	2.17 ^c	1.27	20.35 ^a	15.38 ^a	22.03 ^a	19.25 ^a	6.69	9.74 ^a	7.93 ^a	9.95 ^a	9.21 ^b	8.38	4.23	3.65
N8	4.02 ^a	2.92 ^a	4.33 ^a	3.76 ^c	2.53	3.12 ^a	2.48 ^a	3.27 ^a	2.96 ^c	1.70	21.11 ^a	19.60 ^a	17.10 ^a	19.27 ^a	10.64	10.82 ^a	13.90 ^a	9.17 ^a	11.29 ^b	9.32	9.15	3.07
N12	5.19 ^a	2.80 ^a	3.98 ^a	3.99 ^c	3.19	3.58 ^a	3.33 ^a	2.48 ^a	3.13 ^c	1.83	23.02 ^a	20.57 ^a	18.61 ^a	20.73 ^a	6.71	16.41 ^a	10.10 ^a	12.47 ^a	12.99 ^b	10.21	7.91	3.86
N16	6.38 ^a	3.29 ^a	3.80 ^a	4.49 ^c	4.38	3.52 ^a	3.73 ^a	3.57 ^a	3.61 ^c	3.82	16.53 ^a	20.31 ^a	20.58 ^a	19.14 ^a	5.45	13.37 ^a	8.62 ^b	7.25 ^b	9.75 ^b	9.25	2.87	4.02
Mean	4.83	3.08	3.45	3.79^c		3.08	2.73	3.09	2.97^c		20.25	18.97	19.58	19.60^a		12.59	10.14	9.71	10.81^b	9.29		1.82
LSD for fertilization	4.14	2.20	2.35			2.40	2.51	1.90			6.63	5.82	9.20			6.34	7.26	5.25				
	2021 year																					
N0	1.88 ^a	1.53 ^a	1.78 ^a	1.73 ^c	0.84	2.12 ^a	2.43 ^a	1.85 ^a	2.13 ^c	0.61	15.15 ^a	14.12 ^a	14.50 ^a	14.59 ^a	3.19	9.13 ^a	9.08 ^a	9.47 ^a	9.23 ^b	6.92	3.93	0.62
N8	1.85 ^a	1.40 ^a	1.62 ^a	1.62 ^b	0.93	2.17 ^a	1.50 ^a	1.85 ^a	1.84 ^b	0.81	11.98 ^a	9.73 ^a	8.97 ^a	10.23 ^a	3.50	10.95 ^a	9.45 ^{ab}	8.20 ^b	9.53 ^a	5.81	2.60	2.01
N12	2.23 ^a	1.72 ^a	1.82 ^a	1.92 ^c	0.93	2.67 ^a	1.78 ^{ab}	1.63 ^b	2.03 ^c	0.97	12.73 ^a	9.92 ^b	9.98 ^{ab}	10.88 ^a	2.78	8.12 ^a	7.68 ^a	9.58 ^a	8.46 ^b	5.82	4.00	1.87
N16	1.87 ^{ab}	2.07 ^a	1.47 ^b	1.80 ^c	0.57	1.82 ^a	1.87 ^a	1.88 ^a	1.86 ^c	1.06	11.03 ^a	8.45 ^a	9.25 ^a	9.58 ^a	3.55	7.62 ^a	8.23 ^a	8.23 ^a	8.03 ^b	5.32	2.78	1.32
Mean	1.96	1.68	1.67	1.77^c		2.20	1.90	1.80	1.97^c		12.72	10.56	10.68	11.32^a		8.96	8.61	8.87	8.81^b	5.97		1.18
LSD for fertilization	0.89	0.65	0.83			1.00	0.59	0.89			3.29	2.96	3.20			2.59	3.47	3.66				
	Average for the period																					
N0	2.20	1.90	1.41	1.84		1.97	1.85	2.16	1.99		15.26	12.30	14.53	14.03		8.93	8.67	9.51	9.04	6.73		
N8	2.18	1.63	2.25	2.02		2.08	1.76	2.00	1.95		13.91	12.83	11.42	12.72		9.66	10.27	8.32	9.42	6.53		
N12	2.64	1.67	2.11	2.14		2.36	2.17	1.65	2.06		14.55	13.00	12.21	13.25		10.83	8.25	9.71	9.60	6.76		
N16	2.92	1.99	1.98	2.30		2.14	2.22	2.25	2.20		12.21	12.36	12.78	12.45		9.19	7.80	7.46	8.15	6.28		
Mean	2.49	1.80	1.94	2.08		2.14	2.00	2.02	2.05		13.98	12.62	12.74	13.11		9.65	8.75	8.75	9.05	6.57		

Table 10. Grain weight per ear of barley varieties grown under different conditions by year and average for the period 2019-2021

Factors	Grain weight per ear																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	1.18 ^a	1.31 ^a	1.27 ^a	1.25 ^c	0.20	1.43 ^a	1.44 ^a	1.23 ^b	1.37 ^c	0.18	2.79 ^a	2.63 ^{ab}	2.39 ^b	2.60 ^a	0.29	2.45 ^a	2.32 ^{ab}	2.07 ^b	2.28 ^b	1.88	0.27	0.30
N8	1.50 ^a	1.45 ^a	1.49 ^a	1.48 ^c	0.14	1.46 ^a	1.54 ^a	1.47 ^a	1.49 ^c	0.20	2.97 ^a	2.86 ^a	2.82 ^a	2.88 ^a	0.29	2.71 ^a	2.61 ^{ab}	2.49 ^b	2.60 ^b	2.11	0.18	0.14
N12	1.54 ^a	1.54 ^a	1.60 ^a	1.56 ^c	0.11	1.52 ^a	1.57 ^a	1.48 ^a	1.52 ^c	0.18	3.04 ^a	2.81 ^b	2.79 ^b	2.88 ^a	0.20	2.71 ^a	2.62 ^{ab}	2.50 ^b	2.61 ^b	2.14	0.20	0.16
N16	1.54 ^a	1.54 ^a	1.47 ^a	1.52 ^b	0.14	1.51 ^a	1.48 ^a	1.46 ^a	1.48 ^b	0.11	2.88 ^a	2.71 ^a	2.69 ^a	2.76 ^a	0.38	2.98 ^a	2.53 ^{ab}	2.31 ^b	2.60 ^a	2.09	0.61	0.35
Mean	1.44	1.46	1.46	1.45^c		1.48	1.51	1.41	1.47^c		2.92	2.75	2.67	2.78^a		2.71	2.52	2.34	2.53^b	2.06		0.21
LSD for fertilization	0.17	0.11	0.13			0.17	0.15	0.17			0.22	0.24	0.39			0.55	0.22	0.17				
	2020 year																					
N0	0.77 ^a	0.71 ^a	0.83 ^a	0.77 ^c	0.25	1.07 ^a	1.11 ^a	0.94 ^a	1.04 ^{bc}	0.25	1.23 ^{ab}	1.58 ^a	0.96 ^b	1.26 ^{ab}	0.61	1.49 ^a	1.49 ^a	1.29 ^a	1.43 ^a	1.12	0.54	0.32
N8	0.79 ^{ab}	0.83 ^a	0.63 ^b	0.75 ^b	0.16	1.08 ^a	0.97 ^a	0.91 ^a	0.99 ^{ab}	0.34	0.98 ^a	1.39 ^a	1.20 ^a	1.19 ^a	0.70	1.26 ^a	1.08 ^a	1.23 ^a	1.19 ^a	1.03	0.50	0.25
N12	0.77 ^a	0.82 ^a	0.70 ^a	0.76 ^c	0.36	1.00 ^a	1.03 ^a	0.97 ^a	1.00 ^b	0.25	1.03 ^a	1.01 ^a	1.04 ^a	1.03 ^b	0.45	1.07 ^a	1.31 ^a	1.17 ^a	1.18 ^a	0.99	0.54	0.14
N16	0.58 ^a	0.65 ^a	0.74 ^a	0.66 ^c	0.43	1.02 ^a	0.96 ^a	0.92 ^a	0.97 ^{bc}	0.36	1.49 ^a	1.00 ^b	0.83 ^b	1.11 ^{ab}	0.41	1.25 ^a	1.34 ^a	1.41 ^a	1.33 ^a	1.02	0.41	0.35
Mean	0.73	0.75	0.73	0.74^d		1.04	1.02	0.94	1.00^c		1.18	1.25	1.01	1.15^b		1.27	1.31	1.28	1.28^a	1.04		0.14
LSD for fertilization	0.35	0.31	0.28			0.28	0.26	0.31			0.55	0.39	0.63			0.48	0.50	0.48				
	2021 year																					
N0	1.02 ^a	0.96 ^{ab}	0.93 ^b	0.97 ^b	0.09	1.10 ^a	0.89 ^b	0.93 ^b	0.97 ^b	0.11	2.30 ^a	2.08 ^a	1.64 ^b	2.01 ^a	0.27	2.35 ^a	1.84 ^b	1.67 ^b	1.96 ^a	1.48	0.38	0.49
N8	1.11 ^a	1.09 ^a	1.11 ^a	1.10 ^c	0.09	1.07 ^a	1.05 ^a	1.01 ^a	1.04 ^c	0.09	2.51 ^a	2.63 ^a	2.65 ^a	2.60 ^a	0.34	2.51 ^a	2.45 ^{ab}	2.29 ^b	2.42 ^b	1.79	0.18	0.14
N12	1.13 ^a	1.13 ^a	1.05 ^a	1.10 ^c	0.20	1.05 ^a	1.04 ^a	1.01 ^a	1.03 ^c	0.14	2.56 ^a	2.39 ^a	2.49 ^a	2.48 ^a	0.43	2.23 ^a	2.24 ^a	2.18 ^a	2.21 ^b	1.71	0.36	0.09
N16	1.12 ^a	1.16 ^a	1.08 ^a	1.12 ^b	0.16	1.09 ^a	1.12 ^a	1.02 ^a	1.08 ^b	0.14	2.59 ^a	2.33 ^a	2.49 ^a	2.47 ^a	0.36	2.46 ^a	2.09 ^b	2.24 ^{ab}	2.26 ^a	1.73	0.27	0.23
Mean	1.10	1.09	1.04	1.08^b		1.08	1.03	0.99	1.03^b		2.49	2.36	2.32	2.39^a		2.39	2.16	2.10	2.22^a	1.68		0.18
LSD for fertilization	0.13	0.17	0.09			0.11	0.11	0.15			0.33	0.35	0.35			0.26	0.31	0.31				
	Average for the period																					
N0	0.99	0.99	1.01	1.00		1.20	1.15	1.03	1.13		2.11	2.10	1.66	1.96		2.10	1.88	1.68	1.89	1.50		
N8	1.13	1.12	1.08	1.11		1.20	1.19	1.13	1.17		2.15	2.29	2.22	2.22		2.16	2.05	2.00	2.07	1.64		
N12	1.15	1.16	1.12	1.14		1.19	1.21	1.15	1.18		2.21	2.07	2.11	2.13		2.00	2.06	1.95	2.00	1.61		
N16	1.08	1.12	1.10	1.10		1.21	1.19	1.13	1.18		2.32	2.01	2.00	2.11		2.23	1.99	1.99	2.07	1.62		
Mean	1.09	1.10	1.08	1.09		1.20	1.19	1.11	1.17		2.20	2.12	2.00	2.11		2.12	2.00	1.91	2.01	1.60		

Table 11. Mass per 1000 grains of barley varieties grown under different conditions by year and average for the period 2019-2021

Factors	Mass per 1000 grains																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	52.88 ^a	52.87 ^a	54.48 ^a	53.41 ^a	2.40	53.50 ^{ab}	54.27 ^a	52.54 ^b	53.44 ^a	1.60	41.48 ^a	41.33 ^a	40.53 ^a	41.11 ^b	2.53	42.15 ^a	42.86 ^a	41.63 ^a	42.21 ^b	47.54	3.12	1.41
N8	56.46 ^a	55.05 ^a	55.46 ^a	55.66 ^a	3.39	53.66 ^a	53.60 ^a	52.50 ^a	53.25 ^b	3.37	39.79 ^{ab}	38.78 ^b	42.53 ^a	40.36 ^c	3.25	41.14 ^a	40.12 ^a	39.64 ^a	40.30 ^c	47.40	2.51	2.17
N12	55.29 ^b	56.30 ^{ab}	58.08 ^a	56.55 ^a	2.58	52.14 ^a	53.71 ^a	53.35 ^a	53.07 ^b	3.28	38.61 ^a	37.89 ^a	37.18 ^a	37.89 ^d	3.96	41.40 ^a	40.88 ^a	39.26 ^a	40.51 ^c	47.01	2.58	1.99
N16	54.89 ^a	56.21 ^a	57.69 ^a	56.26 ^a	3.80	53.68 ^a	52.14 ^a	52.11 ^a	52.64 ^b	3.62	37.43 ^a	35.78 ^a	37.74 ^a	36.98 ^c	4.36	38.09 ^a	37.58 ^a	38.47 ^a	38.04 ^c	45.98	2.33	1.89
Mean	54.88	55.11	56.43	55.47 ^a		53.25	53.43	52.63	53.10 ^b		39.33	38.45	39.50	39.09 ^d		40.70	40.36	39.75	40.27 ^c	46.98		1.13
LSD for fertilization	3.03	2.07	3.64			3.71	2.75	2.25			3.62	3.10	3.66			2.70	2.62	2.31				
	2020 year																					
N0	40.23 ^a	39.08 ^a	40.55 ^a	39.95 ^b	5.92	45.28 ^a	46.10 ^a	42.41 ^a	44.60 ^a	5.45	33.16 ^a	34.73 ^a	32.40 ^a	33.43 ^c	2.35	32.13 ^a	30.85 ^a	30.48 ^a	31.15 ^c	37.28	3.96	2.40
N8	39.51 ^{ab}	40.76 ^a	37.73 ^b	39.33 ^b	2.24	43.66 ^a	42.33 ^a	42.20 ^a	42.73 ^a	5.31	34.65 ^a	34.38 ^a	32.75 ^b	33.93 ^c	1.60	28.26 ^a	29.51 ^a	28.50 ^a	28.76 ^d	36.19	5.24	1.99
N12	39.61 ^a	39.37 ^a	37.31 ^a	38.76 ^b	4.41	42.99 ^a	42.74 ^a	41.03 ^a	42.25 ^a	3.57	32.25 ^a	31.63 ^a	33.03 ^a	32.30 ^c	2.42	30.97 ^a	29.28 ^a	30.50 ^a	30.25 ^d	35.89	3.66	1.89
N16	38.01 ^a	37.26 ^a	39.24 ^a	38.17 ^b	7.57	43.28 ^a	43.61 ^a	42.75 ^a	43.21 ^a	4.52	32.28 ^b	34.89 ^a	31.34 ^b	32.84 ^c	2.44	33.31 ^a	30.75 ^a	30.16 ^a	31.41 ^c	36.41	6.03	2.56
Mean	39.34	39.12	38.71	39.06 ^b		43.80	43.70	42.10	43.20 ^a		33.09	33.91	32.38	33.13 ^c		31.17	30.10	29.91	30.39 ^d	36.44		1.36
LSD for fertilization	4.49	5.91	5.14			4.93	3.82	4.99			2.25	2.03	2.18			4.97	4.47	4.49				
	2021 year																					
N0	49.76 ^a	49.18 ^a	48.79 ^a	49.24 ^a	3.64	46.31 ^a	46.55 ^a	45.40 ^a	46.09 ^b	3.59	40.29 ^a	38.55 ^a	37.69 ^a	38.84 ^c	3.89	42.24 ^a	40.34 ^{ab}	39.38 ^b	40.65 ^c	43.71	2.31	1.99
N8	47.05 ^a	45.41 ^a	46.08 ^a	46.18 ^a	5.18	41.36 ^a	42.10 ^a	42.21 ^a	41.89 ^b	3.39	34.75 ^a	37.24 ^a	34.55 ^a	35.51 ^c	5.29	37.44 ^a	35.53 ^a	36.15 ^a	36.37 ^c	39.99	2.71	1.92
N12	45.20 ^a	44.21 ^a	45.83 ^a	45.08 ^a	7.14	42.48 ^a	40.81 ^a	40.60 ^a	41.30 ^b	5.90	33.59 ^a	31.03 ^a	33.19 ^a	32.60 ^c	5.29	31.83 ^b	32.70 ^{ab}	35.55 ^a	33.36 ^c	38.09	3.62	2.56
N16	42.86 ^a	44.60 ^a	45.38 ^a	44.28 ^a	5.36	40.10 ^a	42.30 ^a	38.51 ^a	40.30 ^b	4.75	34.44 ^a	31.21 ^a	30.85 ^a	32.17 ^c	4.43	34.11 ^a	32.40 ^a	32.54 ^a	33.02 ^c	37.44	5.04	3.00
Mean	46.22	45.85	46.52	46.20 ^a		42.56	42.94	41.68	42.40 ^b		35.77	34.51	34.07	34.78 ^c		36.41	35.24	35.91	35.85 ^c	39.81		1.20
LSD for fertilization	5.17	6.41	3.95			4.58	4.08	4.40			5.30	3.75	4.62			2.31	3.82	3.97				
	Average for the period																					
N0	47.62	47.04	47.94	47.53		48.36	48.97	46.78	48.04		38.31	38.20	36.87	37.79		38.84	38.02	37.16	38.01	42.84		
N8	47.67	47.07	46.42	47.05		46.23	46.01	45.64	45.96		36.40	36.80	36.61	36.60		35.61	35.05	34.76	35.14	41.19		
N12	46.70	46.63	47.07	46.80		45.87	45.75	44.99	45.54		34.82	33.52	34.47	34.27		34.73	34.29	35.10	34.71	40.33		
N16	45.25	46.02	47.44	46.24		45.69	46.02	44.46	45.39		34.72	33.96	33.31	34.00		35.17	33.58	33.72	34.16	39.95		
Mean	46.81	46.69	47.22	46.91		46.54	46.69	45.47	46.23		36.06	35.62	35.32	35.67		36.09	35.24	35.19	35.51	41.08		

Table 12. Harvest index for barley varieties grown under different conditions by year and average for the period 2019-2021

Factors	Harvest index																					
	Varieties																					
Fertilization	Kuber					Sayra					Zemela					Bozhin						
Seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	LSD for seeding rates	250 g.s.	350 g.s..	450 g.s.	Mean	Average of varieties for the year	LSD for seeding rates	LSD average for sowing rates
Year	2019 year																					
N0	0.48 ^a	0.44 ^b	0.46 ^{ab}	0.46 ^b	0.02	0.48 ^a	0.46 ^b	0.48 ^a	0.47 ^b	0.02	0.53 ^a	0.52 ^a	0.49 ^a	0.51 ^a	0.05	0.52 ^a	0.53 ^a	0.51 ^a	0.52 ^a	0.49	0.02	0.02
N8	0.48 ^a	0.48 ^a	0.48 ^a	0.48 ^b	0.02	0.48 ^a	0.50 ^a	0.49 ^a	0.49 ^b	0.05	0.54 ^a	0.53 ^a	0.53 ^a	0.53 ^a	0.02	0.56 ^a	0.54 ^a	0.54 ^a	0.55 ^a	0.51	0.02	0.02
N12	0.50 ^a	0.49 ^a	0.49 ^a	0.49 ^b	0.02	0.49 ^a	0.50 ^a	0.50 ^a	0.50 ^b	0.05	0.57 ^a	0.56 ^a	0.56 ^a	0.56 ^a	0.02	0.56 ^a	0.56 ^a	0.57 ^a	0.56 ^a	0.53	0.02	0.02
N16	0.51 ^a	0.51 ^a	0.50 ^a	0.51 ^c	0.02	0.50 ^a	0.50 ^a	0.51 ^a	0.50 ^c	0.05	0.55 ^a	0.55 ^a	0.56 ^a	0.55 ^b	0.02	0.58 ^a	0.57 ^a	0.56 ^a	0.57 ^a	0.53	0.02	0.02
Mean	0.49	0.48	0.48	0.49^b		0.49	0.49	0.50	0.49^b		0.55	0.54	0.54	0.54^a		0.56	0.55	0.54	0.55^a	0.52		0.02
LSD for fertilization	0.02	0.02	0.02			0.04	0.02	0.02			0.02	0.02	0.02			0.02	0.02	0.02				
Year	2020 year																					
N0	0.42 ^a	0.43 ^a	0.43 ^a	0.43 ^a	0.07	0.46 ^a	0.48 ^a	0.46 ^a	0.47 ^a	0.05	0.35 ^a	0.41 ^a	0.33 ^a	0.36 ^b	0.09	0.43 ^a	0.44 ^a	0.45 ^a	0.44 ^a	0.43	0.07	0.05
N8	0.40 ^a	0.44 ^a	0.39 ^a	0.41 ^{ab}	0.09	0.44 ^a	0.43 ^a	0.44 ^a	0.43 ^a	0.07	0.32 ^a	0.41 ^a	0.37 ^a	0.37 ^b	0.14	0.42 ^a	0.37 ^a	0.46 ^a	0.42 ^{ab}	0.41	0.14	0.07
N12	0.42 ^a	0.43 ^a	0.41 ^a	0.42 ^a	0.09	0.42 ^a	0.44 ^a	0.45 ^a	0.44 ^a	0.05	0.33 ^a	0.36 ^a	0.36 ^a	0.35 ^b	0.07	0.39 ^a	0.43 ^a	0.42 ^a	0.41 ^a	0.41	0.09	0.02
N16	0.34 ^a	0.34 ^a	0.41 ^a	0.36 ^b	0.14	0.42 ^a	0.42 ^a	0.43 ^a	0.42 ^{ab}	0.07	0.43 ^a	0.34 ^b	0.32 ^b	0.36 ^b	0.07	0.40 ^c	0.44 ^b	0.49 ^a	0.44 ^a	0.40	0.02	0.07
Mean	0.40	0.42	0.41	0.41^b		0.44	0.44	0.45	0.44^a		0.37	0.38	0.36	0.37^c		0.41	0.42	0.46	0.43^{ab}	0.41		0.02
LSD for fertilization	0.09	0.11	0.07			0.07	0.04	0.07			0.09	0.07	0.13			0.03	0.11	0.07				
Year	2021 year																					
N0	0.45 ^a	0.42 ^a	0.44 ^a	0.44 ^b	0.05	0.49 ^a	0.48 ^a	0.48 ^a	0.48 ^a	0.05	0.51 ^a	0.51 ^a	0.51 ^a	0.51 ^a	0.02	0.49 ^a	0.51 ^a	0.46 ^a	0.49 ^a	0.48	0.09	0.02
N8	0.51 ^a	0.51 ^a	0.51 ^a	0.51 ^a	0.02	0.49 ^b	0.53 ^a	0.52 ^{ab}	0.51 ^a	0.02	0.50 ^a	0.52 ^a	0.54 ^a	0.52 ^a	0.05	0.52 ^a	0.53 ^a	0.53 ^a	0.53 ^a	0.52	0.02	0.02
N12	0.51 ^a	0.51 ^a	0.49 ^a	0.50 ^a	0.05	0.51 ^a	0.53 ^a	0.52 ^a	0.52 ^a	0.05	0.52 ^a	0.49 ^a	0.53 ^a	0.51 ^a	0.07	0.51 ^a	0.52 ^a	0.54 ^a	0.52 ^a	0.51	0.05	0.02
N16	0.50 ^a	0.51 ^a	0.50	0.50 ^a	0.05	0.50 ^a	0.52 ^a	0.52 ^a	0.51 ^a	0.05	0.54 ^a	0.50 ^a	0.53 ^a	0.52 ^a	0.05	0.52 ^a	0.51 ^a	0.52 ^a	0.52 ^a	0.51	0.05	0.02
Mean	0.49	0.49	0.49	0.49^b		0.50	0.52	0.51	0.51^a		0.52	0.51	0.53	0.52^a		0.51	0.52	0.52	0.52^a	0.51		0.02
LSD for fertilization	0.04	0.04	0.04			0.04	0.04	0.04			0.04	0.07	0.04			0.07	0.04	0.07				
Average for the period																						
N0	0.45	0.43	0.44	0.44		0.48	0.47	0.47	0.47		0.47	0.48	0.44	0.46		0.48	0.49	0.47	0.48	0.46		
N8	0.46	0.48	0.46	0.47		0.47	0.49	0.49	0.48		0.46	0.49	0.49	0.48		0.50	0.49	0.51	0.50	0.48		
N12	0.48	0.48	0.46	0.47		0.47	0.49	0.49	0.48		0.48	0.47	0.49	0.48		0.49	0.50	0.52	0.50	0.48		
N16	0.45	0.47	0.47	0.46		0.48	0.48	0.49	0.48		0.51	0.49	0.47	0.49		0.50	0.51	0.52	0.51	0.49		
Mean	0.46	0.47	0.46	0.46		0.48	0.48	0.49	0.48		0.48	0.48	0.47	0.48		0.49	0.50	0.51	0.50	0.48		

Table 13. Analysis of variance of productivity elements of winter barley varieties grown under different conditions for the period 2019-2021

Factors	General brotherhood		Number of productive siblings per plant		Plant height		Class length		Number of sterile spikelets		Number of grains per class		Grain weight in class		Mass per 1000 grains		Harvest index	
	MS	η	MS	η	MS	η	MS	η	MS	η	MS	η	MS	η	MS	η	MS	η
Year	9.448***	3.90	44.834***	17.79	76060.135***	73.48	121.989***	14.38	1172.570***	13.24	9341.274***	6.55	50.617***	37.48	5555.002***	33.96	0.707***	67.06
Genotype	84.031***	51.99	77.711***	46.26	2308.973***	3.35	422.677***	74.71	4301.634***	72.88	81536.775***	85.72	41.934***	46.58	5796.907***	53.16	0.036***	5.07
Seeding rates	2.893***	1.19	1.459***	0.58	258.127***	0.25	5.620***	0.66	35.102***	0.40	535.510***	0.38	0.817***	0.61	16.029***	0.10	0.002*	0.14
Fertilization	19.321***	11.95	25.211***	15.01	7399.098***	10.72	14.827***	2.62	7.145***	0.12	946.050***	0.99	0.656***	0.73	237.314***	2.18	0.011***	1.52
Year x Genotype	4.042***	5.00	1.410***	1.68	1081.104***	3.13	13.294***	4.70	243.503***	8.25	1938.494***	4.08	4.652***	10.33	340.992***	6.26	0.042***	11.94
Year x Seeding rates	1.578***	1.30	1.248***	0.99	90.980***	0.19	0.251***	0.06	8.140***	0.18	30.724***	0.04	0.088***	0.13	8.234**	0.10	0.002**	0.43
Year x Fertilization	6.285***	7.78	6.737***	8.02	2111.348***	6.12	3.747***	1.32	22.944***	0.78	429.361***	0.90	0.561***	1.25	92.128***	1.69	0.015***	4.36
Genotype x Seeding rates	1.157***	1.43	0.649***	0.77	38.218***	0.11	0.243***	0.09	3.927***	0.13	64.077***	0.13	0.120***	0.27	9.145***	0.17	0.001ns	0.24
Genotype x Fertilization	2.328***	4.32	0.873***	1.56	70.765***	0.31	0.593***	0.31	8.975***	0.46	82.038***	0.26	0.068***	0.23	17.932***	0.49	0.001ns	0.57
Seeding rates x Fertilization	0.261***	0.33	0.335***	0.40	37.689***	0.11	0.091**	0.03	5.575***	0.19	33.967***	0.07	0.140***	0.31	3.483**	0.06	0.002*	0.57
Year x Genotype x Seeding rates	0.271***	0.67	0.270***	0.64	23.866***	0.14	0.200***	0.14	4.355***	0.30	20.903***	0.09	0.059***	0.26	3.592**	0.13	0.002**	1.28
Year x Genotype x Fertilization	0.564***	2.09	0.348***	1.24	36.423***	0.31	0.159***	0.17	8.098***	0.82	69.916***	0.44	0.080***	0.53	12.511***	0.69	0.002**	2.04
Year x Seeding rates x Fertilization	0.585***	1.45	0.445***	1.06	57.794***	0.34	0.265***	0.19	5.045***	0.35	11.113***	0.05	0.034**	0.15	3.753**	0.14	0.001ns	0.47
Genotype x Seeding rates x Fertilization	0.351***	1.30	0.222***	0.79	34.300***	0.30	0.148***	0.16	6.412***	0.65	19.649***	0.12	0.080***	0.53	4.045**	0.22	0.002**	1.75
Year x Genotype x Seeding rates x Fertilization	0.714***	5.30	0.449***	3.21	65.651***	1.14	0.215***	0.46	6.149***	1.25	14.127***	0.18	0.045***	0.60	5.891***	0.65	0.001*	2.56

Drought and high temperatures during the growing season lead to the formation of smaller grains. The harvest index varies depending on climatic conditions, with the highest values recorded in 2019 and the lowest in 2020. This shows the strong influence of drought on plant productivity. The results of the analysis of variance show that the genotype and the conditions of the year have the strongest influence on the studied traits (Table 13). The year has a leading role in plant height and harvest index, while for most indicators the leading factor is genetic conditioning. Fertilization has a moderate effect only on some of the traits (general and productive tillering and height), and the seed rate has a minimal and weakly expressed impact. The interactions between the factors are also weakly expressed. In summary, barley productivity is mainly determined by the genotype and climatic conditions, while agrotechnical factors have a more limited role.

1.2.3. Relationship of yield with some indicators related to productivity by year

A projection of yield and some indicators related to productivity for barley varieties in 2019 is presented (Figure 36). Yield is located in the quadrant with positive abscissa and negative ordinate, which indicates a dependence on the conditions of the year, characterized by periods of drought and elevated temperatures. The harvest index and plant height are located near it, with the sharp angles between the vectors indicating a strong positive relationship. The main elements of productivity are located in the positive quadrant - total fraternization, number of productive fraternities, spike length, number and weight of grains in a spike, which are also closely related and contribute to increasing yield. In the opposite part are the mass of 1000 grains and the number of sterile spikelets, which show a negative relationship with yield. The presented PCA biplot for 2020 PC1 differentiates the variants by productivity (Figure 37). In the positive part are yield, height, 1000-grain mass and grain weight per spike, which shows a strong positive relationship between them. In the negative part are variants with lower

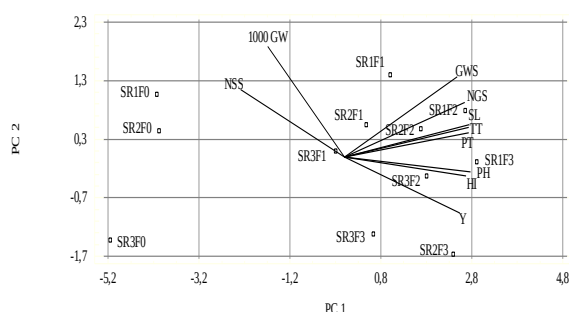


Figure 36. Projection of yield and productivity elements for barley varieties in 2019

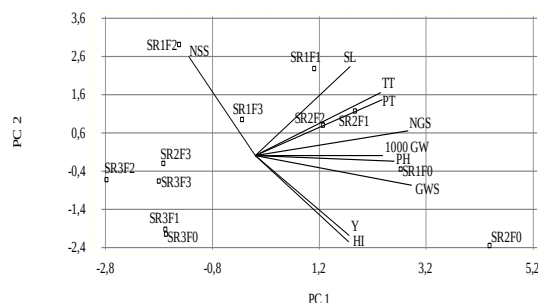
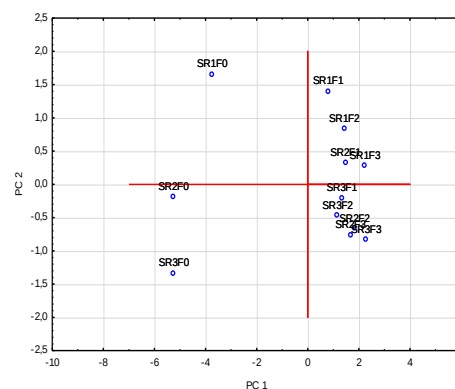
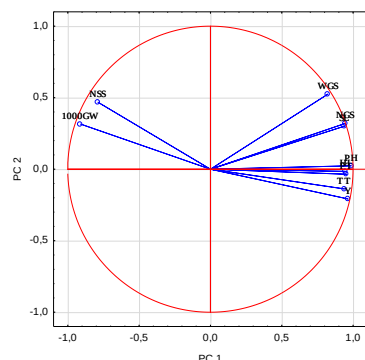


Figure 37. Projection of yield and productivity elements for barley varieties in 2020

The next two figures present the projections for 2021, in which the yield is again located in a quadrant showing dependence on the conditions of the year (Figures 38 and 39). The total fraternization, the number of productive fraternities and the harvest index are strongly positively correlated with it. The number and weight of grains in the ear, the length of the ear and the height of the plants also show a positive relationship with the yield. The mass of 1000 grains and the number of sterile spikelets are again negatively correlated.



Figures 38 and 39. Projection of yield and productivity elements for barley varieties under different cultivation options in 2021

1.2.4. Relationship of yield with some indicators related to productivity at seeding rates

Figure 40 presents a projection of yield and some indicators related to productivity at a seeding rate of 250 g.s. for the period 2019–2021. The positive quadrant contains the yield, total sibling ratio, number of productive siblings and plant height, with the sharp angles between them indicating a strong positive relationship. The positive part of the plane also contains the number of grains in the ear, ear length, harvest index, grain weight and mass of 1000 grains, which depend on the conditions of the year. Only the number of sterile spikelets is located in the negative part and shows a weak and negative relationship with yield.

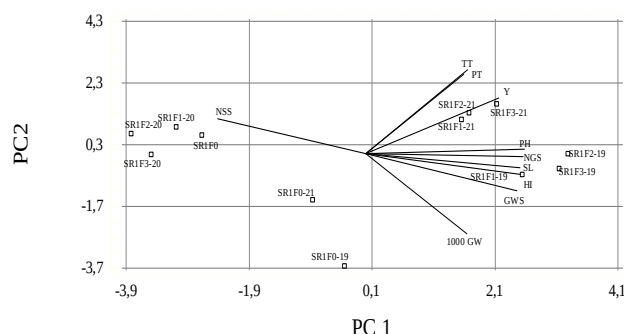
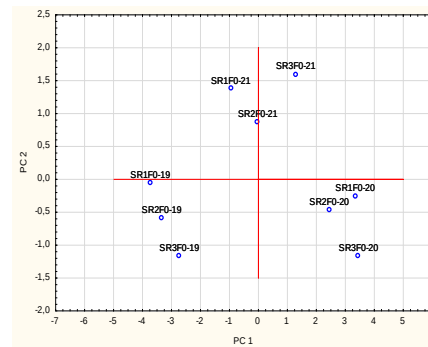
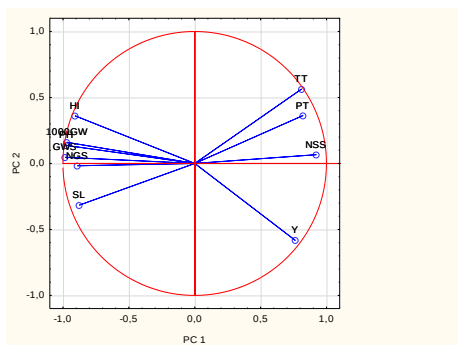


Figure 40. Projection of yield and productivity elements for barley varieties sown at a seeding rate of 250 g.s.

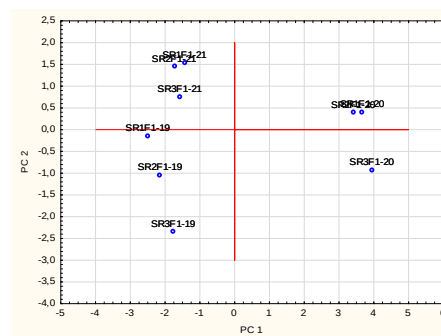
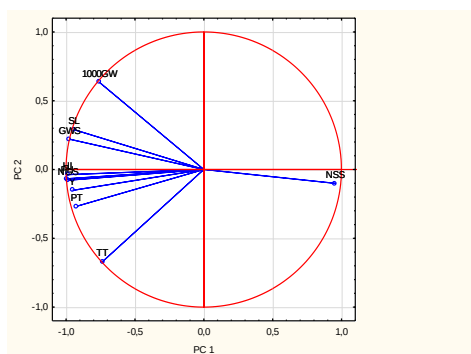
The projection for a seed rate of 350 g.s. shows that the yield and the main productive indicators are oriented in the positive part of PC1, which demonstrates a strong correlation between them (Figure 41). In the negative part is only the number of sterile spikelets, which is negatively correlated. The unfertilized variants in 2019 and 2021 are located in the negative quadrant and are characterized by lower productivity, while this variant in 2020 is closer to the abscissa, which indicates better adaptation to drought. The variants located close to the vectors of the yield components are distinguished by higher productive potential.

In the projection for a seeding rate of 450 g.s., PC1 combines the main yield traits (grain weight, number of ears, weight per 1000 grains), which are strongly positively correlated and determine the yield at high density (Figure 42). The options located in the positive part, are



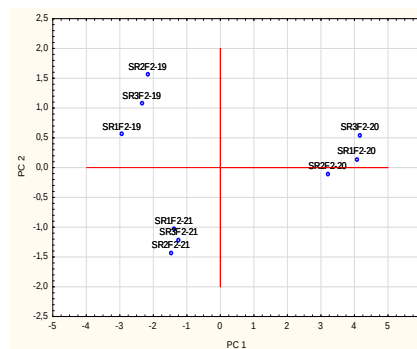
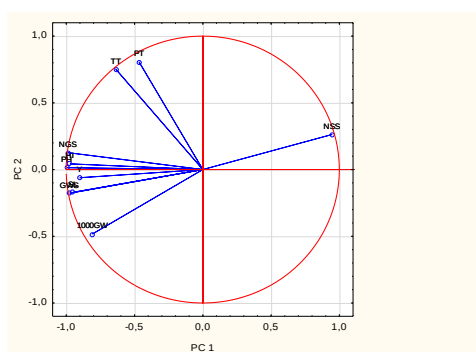
Figures 43 and 44. Projection of yield and productivity elements for barley varieties grown at different seeding rates and years without fertilization

When fertilizing with N8, a strong positive correlation was found between yield, harvest index, 1000-grain weight, ear length, and grain number and weight (Figures 45 and 46). The variants are grouped by year, with 2020 showing the best productivity despite the drought, while 2019 showed the weakest results, especially at 450 g.s.



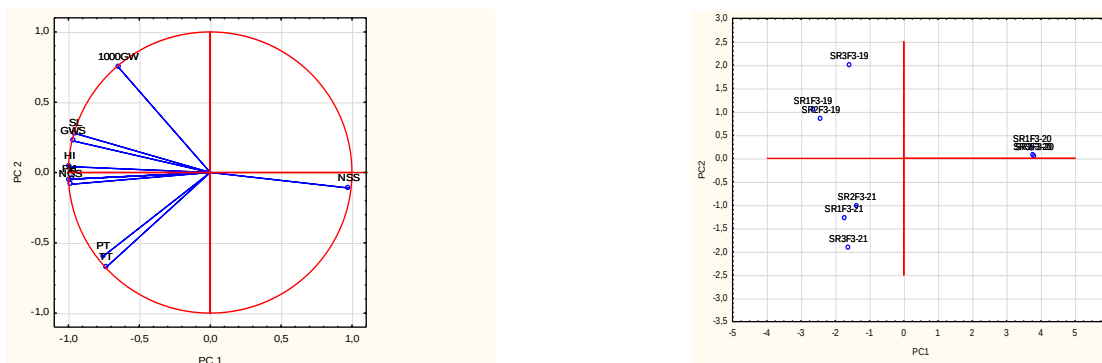
Figures 45 and 46. Projection of yield and productivity elements for barley varieties grown at different seeding rates and years with fertilization rate N8

When fertilizing with N12, the positive relationship between the main yield traits is maintained, with the greatest contribution being made by grain weight, 1000-grain mass, harvest index and number of grains per cluster (Figures 47 and 48). The 2019 variants have lower productivity due to difficulty in absorbing fertilizer during drought. The 2020 variants are statistically different, but this reflects a different structure of the traits, and not necessarily a higher yield. In 2021, the variants have close values and low variability.



Figures 47 and 48. Projection of yield and productivity elements for barley varieties grown at different seeding rates and years with a fertilization rate of N12

When fertilized with N16, most traits are grouped and positively correlated, while the number of sterile spikelets remains negatively correlated (Figures 49 and 50). The mass of 1000 grains is separated as an independent factor related to PC2. The variants from 2020 are similar to each other and clearly distinguished from the other years.



Figures 49 and 50. Projection of yield and productivity elements for barley varieties grown at different seeding rates and years with a fertilization rate of N16

1.3. Influence of growing conditions on seed quality of new barley varieties

Table 14 presents an analysis of the variance of seed quality of new barley varieties to establish the influence of the conditions of the year, genotype and agrotechnical factors. The analysis clearly shows the dominant influence of climatic conditions during the year on the seed quality of barley, as they determine the largest part of the variation in all studied indicators. The genotype also has a significant contribution, especially for germination energy and germination, which confirms the importance of varietal differences. In contrast, seed rate and fertilization have a minimal and mostly statistically insignificant influence, acting rather within the framework of interaction with other factors.

Table 14. Analysis of variance of germination energy, germination and mass of 1000 seeds for barley varieties during the period 2019-2021

Factors	Sprouting energy		Кълняемост		Маса на 1000 семена	
	MS	η	MS	η	MS	η
Year	20977.010***	50.04	1381.431***	45.90	130209.737***	96.62
Genotype	17002.007***	27.05	983.153***	21.78	5104.448***	2.53
Seeding rates	51.698**	0.12	21.420 ns	0.71	46.610***	0.03
Fertilization	234.007***	0.37	17.556 ns	0.39	291.974***	0.14
Year x Genotype	25125.795***	19.98	1685.097***	18.67	2247.971***	0.56
Year x Seeding rates	31.792**	0.04	32.278 ns	0.53	29.503**	0.01
Year x Fertilization	441.295***	0.35	135.153*	1.50	362.648***	0.09
Genotype x Seeding rates	448.733***	0.36	212.858**	2.36	8.057 ns	0.002
Genotype x Fertilization	691.535***	0.37	45.847 ns	0.34	25.398**	0.004
Seeding rates x Fertilization	174.691***	0.14	120.163 ns	1.33	10.884 ns	0.003
Year x Genotype x Seeding rates	787.153***	0.31	162.611 ns	0.90	19.207 ns	0.002
Year x Genotype x Fertilization	806.622***	0.21	138.319 ns	0.51	30.909 ns	0.003
Year x Seeding rates x Fertilization	472.569***	0.19	285.972*	1.58	21.354 ns	0.003
Genotype x Seeding rates x Fertilization	997.434***	0.26	554.059*	2.05	29.185 ns	0.002
Year x Genotype x Seeding rates x Fertilization	1578.597***	0.21	784.806 ns	1.45	53.179 ns	0.001

Task 2. Identification of genotypic differences in the growth activity of seeds of new barley varieties produced under different growing conditions.

Figures 51, 52, 53, 54 present information on genotypic differences in seeds of winter barley varieties in terms of their growth activity. Their seeds were obtained from the variants of the field multifactorial experiment, the idea being to monitor whether different growing conditions affect their growth activity. Higher values are recorded at moderate to high fertilizer rates, and the lowest – at no fertilization and at high density with high fertilization. Varietal differences are observed. Seeds of the Saira variety in all variants form the highest values of the length of the first leaf (Figure 51). This shows that the variety has the fastest growth rate compared to the other varieties. The varieties Bozhin and Zemela in most variants have the lowest values of the length of the first leaf compared to the average values for the studied group. Bozhin responds favorably to high fertilization levels, while for the Zemela variety the length of the first leaf is greater than seeds formed at low seeding rates and low fertilization levels. The length of the coleoptile varies within narrow limits (Figure 52). The highest average values are observed in variants with low fertilization rates (N 8). The varieties Saira and Zemela show a greater length of the coleoptile compared to the others. The number of roots varies slightly (Figure 53). Higher values are found at lower fertilization levels. The largest number of roots is formed by the Kuber variety, and the smallest - by the Bozhin variety. The length of the roots also varies within limited limits (Figure 54). The longest roots are formed in the variant with 450 g.s. and fertilization N 8 kg. There are varietal differences - the Saira variety has the longest roots, and the Bozhin variety has the shortest.

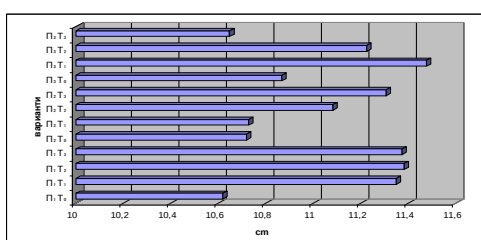


Figure 51. Length of the first leaf in winter barley genotypes by variant, average for the period 2019-2021

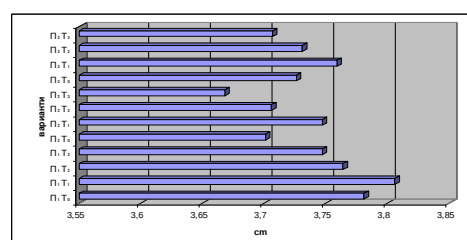


Figure 52. Coleoptile length in winter barley genotypes by variants, average for the period 2019-2021

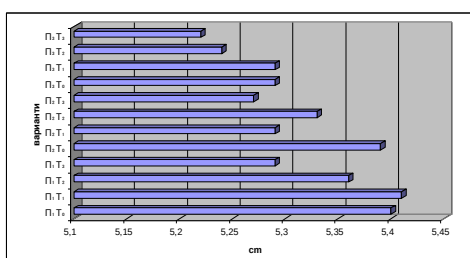


Figure 53. Number of roots in winter barley genotypes by variant, average for the period 2019-2021

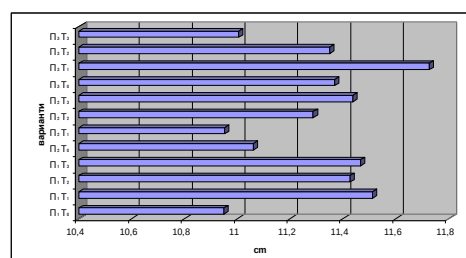


Figure 54. Root length of winter barley genotypes and variants on average for the period 2019-2021

An analysis of variance is presented for winter barley varieties to determine the influence of growing factors (Table 15). It should be borne in mind that the influence of seed growing conditions on growth activity is indirect and relatively weak. For the length of the first leaf, the genotype has the greatest importance ($\eta=36.78\%$), while fertilization has a weaker influence ($\eta=3.96\%$), and the year and seed rate have a minimal effect. The interaction between year and genotype ($\eta=9.80\%$) is more significant. A similar trend is observed for coleoptile length, where genotype is the leading factor ($\eta=33.66\%$), followed by year ($\eta=14.79\%$) and fertilization ($\eta=2.34\%$), with the year $\times$ genotype interaction also having a significant role ($\eta=13.03\%$). For the number of roots, genotype ($\eta=44.27\%$) and year ($\eta=43.77\%$) have almost equal influence, and their interaction is also significant ($\eta=5.31\%$). For root length, year ($\eta=23.07\%$) is a stronger factor than genotype ($\eta=18.25\%$), with the greatest influence being exerted by the combined action of all factors ($\eta=10.54\%$).

Table 15. Analysis of variance of growth rate of winter barley varieties from seeds obtained under different growing conditions

Factors	Length of the first sheet		Coleoptile length		Number of roots		Root length	
	MS	η	MS	η	MS	η	MS	η
Year	3.895***	1.03	1.413***	14.79	38.197***	43.77	77.749***	23.07
Genotype	46.178***	36.78	1.072***	33.66	12.876***	44.27	20.500***	18.25
Seeding rates	1.670***	0.89	0.102**	2.13	0.332***	0.77	1.035***	0.61
Fertilization	4.965***	3.96	0.075**	2.34	0.164***	0.56	1.200***	1.07
Year x Genotype	12.305***	9.80	0.415***	13.03	1.546***	5.31	8.977***	7.99
Year x Seeding rates	4.316***	2.29	0.012ns	0.24	0.078**	0.18	6.231***	3.70
Year x Fertilization	3.818***	3.04	0.030**	0.94	0.123**	0.42	0.075*	0.07
Genotype x Seeding rates	3.204***	5.11	0.073**	4.56	0.091**	0.63	2.762***	4.92
Genotype x Fertilization	2.373***	5.67	0.048**	4.48	0.031*	0.32	1.961***	5.24
Seeding rates x Fertilization	3.252***	5.18	0.006ns	0.36	0.024ns	0.17	2.546***	4.53
Year x Genotype x Seeding rates	1.859***	2.96	0.098***	6.12	0.061**	0.42	2.171***	3.87
Year x Genotype x Fertilization	1.909***	4.56	0.038**	3.58	0.093***	0.96	2.292***	6.12
Year x Seeding rates x Fertilization	2.090***	3.33	0.030**	1.91	0.075**	0.51	1.010***	1.80
Genotype x Seeding rates x Fertilization	1.625***	7.77	0.023*	4.31	0.042**	0.87	1.538***	8.22
Year x Genotype x Seeding rates x Fertilization	1.597***	7.63	0.040**	7.55	0.041**	0.84	1.974***	10.54

The highest values of the fresh weight of the first leaf and coleoptile are recorded in the variants 350 g.s. with N12 and 250 g.s. with N8. The lowest fresh and dry weight was found at 350 g.s. without fertilization. The highest dry weight is formed at higher density and higher fertilizer rates. The highest percentage of dry matter is recorded at 450 g.s. and fertilization with

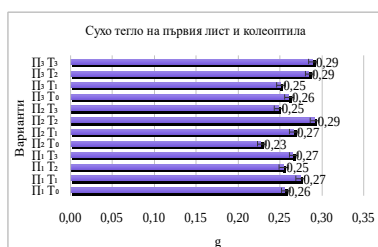


Figure 55. Fresh weight of the first leaf and coleoptile in winter barley genotypes by variant, average for the period 2019-2021



Figure 56. Dry weight of the first leaf and coleoptile in winter barley genotypes by variant, average for the period 2019-2021



Figure 57. Percentage of dry matter in the first leaf and coleoptile in winter barley genotypes by variant, average for the period 2019-2021

density (250 g.s.) and fertilization with N 8 and 12 kg/da. At 350 g.s., the best results are N12 and N16, which is an indicator of more intensive initial growth of the plants (Figure 55, 56 and 57). The highest values of fresh root weight are observed in seeds of crops with low obtained at N 12 kg/da, and at the highest density (450 g.s.) - at N 16 kg/da. The lowest values are recorded at 450 g.s. with low fertilization (N 8), which indicates weaker growth and less developed roots. The most favorable conditions are the variants 250 g.s. and N 8 and N 12 (Figure 58). The dry root weight varies slightly between the different variants. Higher values are found at 250 g.s. without fertilization and 450 g.s. with N 12 (Figure 59). The highest percentage of dry matter is recorded at 450 g.s. and N 8 (30.97%), 250 g.s. and N 16 (27.27%) and 250 g.s. without fertilization (27.08%). In these variants, the fresh weight is lower, but the dry weight remains relatively high, which leads to a higher percentage of dry matter. This indicates less watered and smaller roots with lower conductivity (Figure 60).

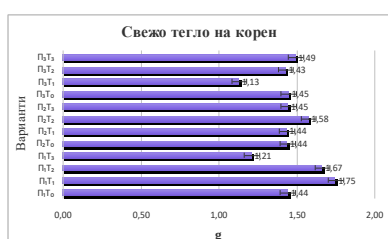


Figure 58. Fresh weight of roots in winter barley genotypes on average for the period 2019-2021

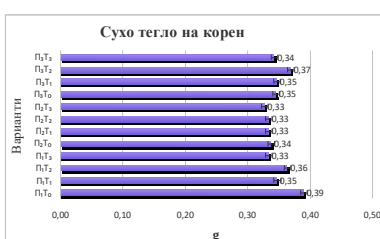


Figure 59. Dry root weight of winter barley genotypes on average for the period 2019-2021

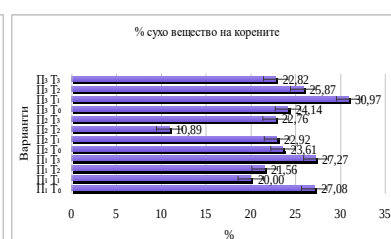


Figure 60. Percentage of dry matter in roots in winter barley genotypes on average for the period 2019-2021

The analysis of variance shows that in the fresh weight of the first leaf and coleoptile the leading factor is the genotype ($\eta=64.62\%$), followed by the year ($\eta=25.59\%$) (Table 16). The influence of the interactions is weak. In the fresh weight of the roots the genotype again dominates ($\eta=61.41\%$), and the year is also important ($\eta=10.08\%$). The interactions between the factors have a more significant influence. The genotype has a strong impact on the dry

Table 16. Analysis of variance of growth rate in winter barley varieties from seeds obtained under different growing conditions

Factors	Fresh weight of first leaf and coleoptile		Dry weight of the first leaf and coleoptile		Fresh weight of root		Dry weight of root	
	MS	η	MS	η	MS	η	MS	η
Year	17.354***	25.591	0.131***	19.003	3.361***	10.075	0.180***	20.259
Genotype	29.213***	64.618	0.259***	56.142	13.658***	61.409	0.315***	53.236
Seeding rates	0.121**	0.178	0.002**	0.289	0.200***	0.600	0.001*	0.113
Fertilization	0.437***	0.967	0.006***	1.373	0.035*	0.156	0.007***	1.182
Year x Genotype	0.357***	1.581	0.015***	6.575	0.230***	2.070	0.023***	7.653
Year x Seeding rates	0.235***	0.695	0.007***	1.951	0.158***	0.949	0.007***	1.688
Year x Fertilization	0.111***	0.491	0.002***	1.011	0.128***	1.152	0.001**	0.506
Genotype x Seeding rates	0.074**	0.327	0.005***	2.384	0.432***	3.886	0.012***	4.052
Genotype x Fertilization	0.078**	0.521	0.002***	1.228	0.031*	0.422	0.001**	0.394
Seeding rates x Fertilization	0.065**	0.287	0.001*	0.289	0.055**	0.498	0.001**	0.394
Year x Genotype x Seeding rates	0.058**	0.513	0.002***	2.023	0.213***	3.831	0.003***	2.138
Year x Genotype x Fertilization	0.093***	1.240	0.002***	2.168	0.125***	3.363	0.002***	1.576
Year x Seeding rates x Fertilization	0.088***	0.779	0.001*	0.578	0.163***	2.935	0.001**	0.732
Genotype x Seeding rates x Fertilization	0.052**	0.689	0.001**	1.373	0.115***	3.101	0.002***	2.195
Year x Genotype x Seeding rates x Fertilization	0.057***	1.523	0.001***	3.613	0.103***	5.553	0.002***	3.882

weight of the first leaf and coleoptile ($\eta=56.14\%$) and of the roots ($\eta=53.24\%$). In these indicators, the year is also important, as is the interaction year $\times$ genotype. In summary, the genotype is a major factor for most indicators, while the year is more important for the number and length of roots. The influence of the seed rate and fertilization is weak and mostly indirect.

VI. EXTRACTS

1. Weather conditions are the leading factor for the duration of all phenophases, germination, emergence and yield, with a stronger influence than fertilization and seed rate. High spring temperatures and water deficit shorten spindle formation, heading and flowering, especially in multi-row varieties.

2. Two-row varieties (Kuber, Saira) have faster initial growth and short early phenophases, while multi-row varieties (Zemela, Bozhin) develop phenologically slower and are more sensitive to stress.

3. The influence of nitrogen fertilization and seed rate is limited and manifests itself only in individual years (2019 and 2021).

4. Fertilization with N12 increases the number of productive siblings, grain weight and harvest index, stabilizing the yield, while high rates (N16) reduce productivity. The seeding rate has a moderate effect: sparse and medium crops (250–350 hp) increase the number and weight of grains, and dense (450 hp) - the harvest index and the number of ears.

5. It has been proven that the weather conditions of the year determine the seed yield and the utility coefficient, with high values observed under favorable conditions, and low - during drought.

6. It has been established that the genotype has a determining role in the resistance to abiotic stress, with the Bozhin variety showing high stability under stressful conditions, while Saira has the lowest germination and survival.

7. Seed yield is a complex indicator determined by the total and productive fertility under moderate and optimal fertilization (N8–N12), which act compensatory under adverse conditions. The highest seed yield is achieved when combined with medium to high seeding rates (350–450 hp), ensuring synchronization between morphological and productive indicators.

8. Plant height, grain weight in the spike and harvest index have a positive influence on the formation of yield, while sterile spikelets and the mass of 1000 grains, especially under stress conditions, have a negative effect.

9. A flexible approach to fertilization and seeding rate is necessary under abiotic stress, with the choice of a resistant variety and moderate nitrogen fertilization guaranteeing stable productivity and high seed qualities.

10. The conditions of the year are the leading factor in the formation of sowing qualities in barley. They have the strongest influence on the germination energy, germination and especially on the mass of 1000 seeds, which emphasizes their crucial role during the filling and ripening of the grain.

11. The genotype is of essential importance for the sowing indicators of seeds. The two-row varieties Kuber and Saira are distinguished by a higher and more stable germination energy and germination compared to the multi-row varieties Zemela and Bozhin, which proves the importance of the genetic potential for the quality of the seed material.

12. Germination energy is a more sensitive and more informative indicator than germination and serves as a reliable indicator of the physiological state and viability of seeds. Germination is more stable and little influenced by agrotechnical factors (fertilization and seed rate), depending mainly on the genotype and climatic conditions of the year.

13. The mass of 1000 seeds is strongly dependent on the conditions of the year, and the influence of the genotype and agrotechnical factors is significant, but secondary.

14. Nitrogen fertilization has a limited but clear influence: moderate and optimal rates (N8–N12) increase the mass of 1000 seeds and maintain good seed quality, while N16 does not

bring benefits and may have a negative effect. The seeding rate affects productivity slightly, but more significantly the mass of 1000 seeds, with the lower rate (250 hp) favoring the formation of large and high-quality seeds.

15. The interactions between the factors year, genotype, seeding rate and fertilization are more important for germination energy and germination than for the mass of 1000 seeds, which indicates the complex relationship between varietal characteristics and environmental conditions in the formation of viable seeds.

16. Multi-row varieties exhibit higher sensitivity to abiotic stress, especially during drought, which leads to a significant decrease in germination energy and greater variability in seed quality.

17. Initial seed growth depends on genotype and fertilization – the length of the first leaf, coleoptile and roots is determined mainly by varietal characteristics, with Saira and Kuber having the most stable and intensive growth.

VII. SCIENTIFIC CONTRIBUTIONS

1. For the first time, the behavior of new Bulgarian winter barley varieties Kuber, Saira, Zemela and Bozhin in seed production conditions has been studied.

2. Mechanisms of interaction between climate, genotype and agrotechnical factors (fertilization and seed rate) in the formation of yield and seed potential in conditions of climate change have been described.

3. The leading influence of meteorological conditions on the phenological development, productivity and seed qualities of barley has been established, with their impact exceeding that of fertilization and seed rate.

4. Mathematical models of the yield of new barley varieties in seed crops under the conditions of Karnobat have been created.

5. Direct and indirect effects of morphological and productive indicators on yield have been determined, which allows a better understanding of the complex interaction between plant characteristics.

6. It has been found that excessive fertilization during water deficit can reduce plant productivity, expanding knowledge about the interaction between nutrition and abiotic stress.

VIII. SCIENTIFIC AND APPLIED CONTRIBUTIONS

1. Flexible agronomic techniques are recommended, combining optimal variety selection, moderate nitrogen fertilization (N8–N12) and appropriate seeding rate, for stable yield and high seed quality.

2. Optimal fertilization levels and seeding rate for different varieties are determined, which allows minimizing losses during drought and maximizing productivity under favorable conditions.

3. The role of phenological synchronization through fertilization and optimal seeding rate in improving seed quality and increasing yield is clarified.

4. Selection indicators are identified, including general and productive seedling vigor, harvest index and plant height, which can be used to predict yield.

5. A scientifically sound approach to abiotic risk is developed - adapting fertilization and seeding rate to the water regime and drought forecast.

6. A practical recommendation is to use medium to high seeding rates (350–450 hp) and moderate to optimal nitrogen fertilization (N8–N12), under favorable weather conditions and an appropriate genotype to obtain the highest seed yields. This combination ensures an optimal balance between morphological and productive indicators and the compensatory effect of factors.

PUBLISHED SCIENTIFIC ARTICLES RELATED TO THE DISSERTATION

1. Dobрева V., 2019. Seed properties – a basis for increasing grain yield in barley – a review. Field crop studies, vol. XII, 41-54.
2. Dobрева V., D. Valcheva, 2022. Genotypic differences in the fresh and dry weight of the first leaf, coleoptile and roots of seeds of winter barley varieties, Bulgarian Journal of Crop Science, 2022, 59 (5).

ABSTRACT

The dissertation investigates the influence of genotype and growing conditions on seed yield and seed quality in new barley (*Hordeum vulgare* L.) cultivars. The relevance of the topic is determined by the need to develop and implement high-yielding and adaptable varieties under conditions of a changing climate. Despite the reduction of barley cultivation areas in the country in recent years, productivity has increased, which is a result of the introduction of newly bred cultivars. This brings to the forefront the importance of high-quality seed material and the necessity for in-depth research on the factors influencing yield formation.

The aim of the study is to determine the influence of genotype and growing conditions on seed yield and quality in new barley cultivars. To achieve this objective, a multifactorial field experiment and field-laboratory studies were conducted under different nitrogen fertilization rates and seeding densities.

The results show that seed yield and quality are formed under the complex interaction between genotype and environmental conditions. A significant influence of meteorological conditions on phenological development, productivity, and seed quality traits was established. Unfavorable conditions during critical growth stages, such as flowering and grain filling, lead to a decrease in yield and deterioration of seed quality. A significant effect of agronomic factors, including nitrogen fertilization rates and seeding density, on the main yield components was also demonstrated. Optimal combinations of growing conditions were identified for a more complete realization of the productive potential of the cultivars.

Seed yield is a complex trait determined by total and productive tillering under moderate and optimal fertilization (N8–N12), which exhibit compensatory effects under unfavorable conditions. The highest seed yields are achieved in combination with medium to high seeding rates (350–450 viable seeds m⁻²), ensuring synchrony between morphological and productive traits. Positive effects on yield formation are exerted by plant height, grain weight per spike, and harvest index, whereas sterile spikelets and thousand kernel weight, especially under stress conditions, have a negative effect. Under abiotic stress, a flexible approach to fertilization and seeding rate is required, as the selection of a tolerant cultivar combined with moderate nitrogen fertilization ensures stable productivity and high seed quality.

Year-specific environmental conditions are the leading factor in the formation of seed quality in barley. They exert the strongest influence on germination energy, germination capacity, and particularly on thousand kernel weight, highlighting their decisive role during grain filling and maturation. Genotypic differences in germination, germination energy, and seedling growth vigor were identified, which are determined both by hereditary characteristics and by growing conditions.

The obtained results have scientific and practical significance and can be used in barley breeding and in optimizing seed production technologies with the aim of increasing seed yield and improving seed quality.